Energy Research and Development Division

FINAL PROJECT REPORT

Huntington Beach Advanced Energy Community Blueprint

A Scalable, Replicable, and Cost-Effective Model for the future

California Energy Commission

Gavin Newsom, Governor

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PREFACE

The California Energy Commission's Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solution, foster regional innovation and bring ideas from the lab to the marketplace. The California Energy Commission and the state's three largest investor-owned utilities – Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company – were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The Energy Commission is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Huntington Beach Advanced Energy Community Blueprint is the final report for the Huntington Beach Advanced Energy Community project (Contract Number EPC-15-077) conducted by the University of California, Irvine. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

To support statewide environmental goals, local resiliency goals, and the desire to include low income communities in the development of sustainable energy projects, the Huntington Beach Advanced Energy Community project developed tools that can perform community-scale energy conservation measures and distributed energy resource optimization and design. These new tools are capable of capturing the interactions between numerous green energy technologies, allowing a developer to test the technical and economic feasibility of a given combination of technologies. The tools were then used to design an advanced energy community for the disadvantaged community of Oak View, located in Huntington Beach. The resulting design used energy conservation measures to reduce electrical demand by approximately 30 percent, and solar energy with storage to further reduce electrical demand by up to 94 percent. A financial model was also established to use financial structures and mechanisms that support advanced energy community development in low-income communities. In addition, the research also determined the renewable fuel potential of the community along with the potential for an electric car share service.

Keywords: advanced energy community, community energy modeling, community solar, community energy storage, building energy modeling, optimal community design.

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EXECUTIVE SUMMARY

Introduction

California's Renewables Portfolio Standard requires that 33 percent of the state's electricity be powered using renewable resources by 2020, 50 percent by 2026, and 60 percent by 2030. In 2016, the Energy Commission released a solicitation titled, The EPIC Challenge, a two-phase competition to assist California's local governments in meeting these targets. The competition focuses on overcoming financial and regulatory challenges to more widely deploy advanced energy communities. This concept was created to represent the combination of technology types that can (1) reduce energy demand through energy conservation measures, (2) generate energy using renewable sources, and (3) manage community energy flows to optimize service and connection with the surrounding communities. The first phase of the competition is focused on the planning and design of a replicable advanced energy community, inclusive of a master community design, case study, and resources. Phase II will award funding to build-out the design developed under Phase I, and was released in the fall of 2018.

As a Phase I recipient, a team consisting of the Advanced Power and Energy Program at University of California, Irvine, the City of Huntington Beach, Altura Associates, the National Renewable Energy laboratory, Southern California Edison, and Southern California Gas was partnered together to develop tools to optimally design an advanced energy community for the disadvantaged Oak View community. The Huntington Beach Advanced Energy Community project's goal was to install various interworking clean energy technologies in way that could be successfully replicated in other communities.

Project Process

Tool development included the creation of the community-scale energy modeling platform URBANopt. This tool is able to capture the complex relationships between building and community energy use when considering different types of energy conservation measures. Since it is based on the EnergyPlus building energy simulation engine, URBANopt can be expanded to include numerous other energy conservation and renewable generation measures. The current version examines interior and exterior lighting efficiency, plug load efficiency, and structural improvements that can be used to reduce interior heating and cooling loads. Development also included a smart community energy management model that included the DERopt community solar energy and battery energy storage optimization model. Using this model, it is possible to optimally determine the best types and locations of renewable generation within the community, and ensure feasible operation. This model also can be used to evaluate the renewable fuel potential for a community.

During development of the tools, the team also participated in extensive community outreach, which is discussed in more detail, under the Knowledge Transfer section.

Project Results

After completion of tool development, the research team designed the Oak View advanced energy community. The team modeled more than 300 buildings in both URBANopt and DERopt, resulting in the following design elements:

- Community-scale light-emitting diode (LED) upgrades: The team found that LED energy conservation measures were highly cost effective across the entire community. By changing every light fixture to only use LED lighting, electrical energy use could be reduced by 24 percent across the entire community. In addition, simple payback on a community scale LED upgrade could occur within a single year. These benefits are large enough that LED implementation should be done throughout the community regardless of whether the advanced energy community design is implemented.
- Community-scale plug load upgrades: Community scale plug load upgrades consist of multiple different measures taken within each individual building sector. In general, plug load energy conservation measures were found to be less cost effective than LED energy conservation measures. However, in total, plug load energy conservation measures were still found to be economically viable, with a simple payback occurring in between seven to ten years depending on the number of residents who qualify for the Southern California Edison CARE program rates. The research team projects that widespread plug load energy conservation measures could reduce electricity use by 6 percent. The plug load energy conservation measures and applicable sectors are:
    - High efficiency appliances, such as refrigerators and laundry equipment installed across the residential sector.
    - Smart power strips that cut electrical service to connected devices and loads when not in use.
- Community-scale distributed energy resources system: Solar photovoltaic (PV) and electrical energy storage systems can be adopted at each location. After considering the optimization of community benefits and the local utility constraints, the project team proposed a community-scale distributed energy resource system including the required sizes and locations for solar PV and energy storage. The resulting system was designed to minimize the cost of pushing the community towards net zero energy. Since the proposed technologies affect electrical use directly, the team presented the model results in terms of approaching net zero electrical energy. Considering the size of the industrial loads in the community, it was impossible to achieve net zero electrical energy, but net electrical use can be reduced by up to 63 percent, resulting in a total reduction in net electrical use by nearly 94 percent when also considering energy conservation measures. The system components consisted of:
    - Community-wide solar PV used to produce renewable electricity, offsetting nonrenewable generation supplied by the local utility grid. In addition to providing renewable energy, certain solar PV installations were designed to be mounted on shading structures, providing shading in parking lots. This

additional amenity reduced the heating of community parking lots and blacktop areas, and provided a service to local residents, employees, and volunteers.

    - Electrical energy storage to support solar PV generation and enable feasible distributed energy resource integration with the utility grid. The electrical energy storage system was optimized to minimize cost while supporting the goal of approaching net zero energy, resulting in a tailor-made system perfectly suited for the Oak View community.

- Community-scale energy data acquisition and management: Part of advanced energy community development is determining whether projected benefits are realized and understanding differences between the modeled/designed system and the actual community. The team implemented a community-wide energy data capture system to allow for continuous benchmarking of both of the design tools and, more importantly, the performance of the advanced energy community. By implementing the data acquisition system, community energy can be managed so that distributed energy resource systems are operated to maximize community benefit.

In addition to the project components aimed at reducing greenhouse gas emissions and electricity demand, the team explored the production of renewable gas and an electric car share service. The results of renewable gas production showed that the conversion of solar PV into fuel, such as hydrogen, could be used to meet a large portion of the community energy demand or be injected into the natural gas pipeline. However, the currently available processes necessary for the renewable fuel production and injection into the pipeline are prohibitively expensive for the scale of the project. Biogas production using the waste streams transferred through the waste transfer facility also have the potential to produce renewable fuel, when only considering waste from the Oak View community, the amount of fuel generation decreases to approximately 100 kilowatts average output. Finally, the car share service was projected to need 18 vehicles but due to difficulty with securing parking throughout the community, the plan was not pursued.

The team believes the following items are critical for developing an advanced energy community:

- Early establishment of relationships with community organizations
- Early development of commercial and industrial energy improvements
- Using technical tools (such as URBANopt and DERopt) in developing community-scale energy projects
- Establishment of quantifiable criteria for making development decisions

Project Benefits

Total potential benefits of the advanced energy community system include reducing the average electrical demand by 2.77 megawatts, allowing for customer cost savings due to reduced energy bills, as well as reduced strain on the local utility grid. Additionally, greenhouse gas emissions can be reduced by up to 6,849 metric tons per year.

In total, the project yielded design tools that will be critical in optimal design of an advanced energy community. Using these tools, the team developed an advanced energy community design for the Oak View community, with an estimated payback period of 15-20 years. This design will be proposed for implementation for Phase II of the EPIC Challenge, which is expected to begin in 2019 and implemented over the following five – six years.

Knowledge Transfer

During project development, the team provided extensive community outreach to residents and local businesses, educating them on the advanced energy community's technologies, potential, and utility programs that can be used to lower their electricity costs. Digital and print media were developed and distributed in both English and Spanish due to the high proportion of Spanish-speaking community members. This included flyers, emails, and a website hosted by the City of Huntington Beach to provide an overview of the project.

The team communicated with the non-residential community stakeholders about potential benefits of the project and provided them with professional energy auditing services. This resulted in the support of the local Oak View Elementary School and the Ocean View school district, as well as full-scale support from local businesses.

The energy education workshops included a program aimed at adults to introduce the community to the project and a youth program to educate local children about energy, both of which took place over six weeks. The adult program covered energy efficiency and low-cost utility options, described the current advanced energy community project, and solicited feedback about which technologies or improvements should be included. Each workshop covered a different topic, with the final week culminating in a sustainable energy-themed version of the game Lotería, a bingo-style card game popular in Mexico and Central America. This modified game acted as an engaging educational tool while encouraging attendance at the workshops.

The youth program was held at two locations, the Oak View Library and the Oak View Boys and Girls Club. Both locations are widely used by local residents and has established after-school enriching activities into which the project's curriculum was incorporated. The material covered was varied to cater to the entire age range of the children in attendance. Outreach organizers utilized creative games and experiments to cover topics such as energy efficiency, jobs in the energy sector, as well as science, technology, engineering and math lessons with an emphasis on environmental and sustainability concepts.

In addition to these educational outreach programs, the team created a workforce development plan to be rolled out in phase II of the project. Careers in energy efficiency and renewables are expected to flourish in the coming years, and the workforce development plan sought to help community residents tap into this expanding field. The goal of the program was to create literature to communicate information about the various school and trade programs in the industry. A portion of the curriculum was aimed at young adults and emphasized programs at local community colleges that support careers in the field, while a second portion of the program was aimed at those who might be supporting a family or might otherwise be unable to devote much time to the classroom. For this second group the program focused on trades and apprenticeships that could act as paid training. Generally, the workforce development program paired career information with supporting services to help community members overcome some of the barriers to joining the green collar workforce, such as financial aid and work study opportunities, counseling, mental health services, childcare, transportation, English as a second language classes, as well as utility, housing, and food assistance.

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CHAPTER 1: Introduction

California state law requires that 33 percent of all electric demand by 2020, 50 percent by 2026, and 60 percent by 2030 be met with renewable resources (Senate Bill 100, De León, Chapter 312, Statutes of 2018) [1]. These requirements were established to contribute to the goals of Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006), which placed limits on future greenhouse gas emissions [2]. Strategies to achieve the goal of higher renewable penetration and the ultimate goal of reducing greenhouse gas emissions include supporting and mandating 1) increased energy efficiency (EE) for all types of energy loads, 2) more efficient conventional vehicles, 3) alternative fuel vehicles, 4) widespread renewable adoption, 5) more efficient nonrenewable generation that supports renewable generation while reducing environmental impacts, and 6) technologies like energy storage that enable renewable generation. These approaches require changes in the way energy is procured, delivered, and used, and nearly all aspects of energy procurement and use can be addressed at the community level. Buildings and energy-intensive processes within communities can be upgraded using EE. Electric and fuel cell vehicle support infrastructure can be installed locally where alternative fuel vehicles are used. Renewable and sustainable generation, such as solar photovoltaic (PV) panels or high efficiency fuel cells, can be installed in buildings (onsite generation). Energy storage, such as batteries, can be co-located with onsite generation.

Two challenges exist with the adoption of these types of technologies: first, where and how much of each technology should be adopted, and second, how to setup the financial structure to enable economically viable adoption and operation of technologies. When both challenges are overcome and widespread adoption of renewable and sustainable technologies occur, then the resulting community can be considered an advanced energy community (AEC).

To assist local governments overcome these hurdles and spur the deployment of AECs in California, the Energy Commission issued the EPIC Challenge[1], a two-phase competition. In 2016, Phase I was released and provided funding for the planning and design of replicable AECs, including a master community design, case study, tools and other public resources. Phase I recipients were then invited to compete for Phase II funding to build out their designs. Phase II projects are expected to begin in 2019 and will be implemented over the following five to six-year period.

The Energy Commission defines AECs as communities that:

- Provide affordable access to renewable energy generation, EE upgrades, and water efficiency and reuse technologies for all community members.

[1] "The EPIC Challenge: Accelerating the Deployment of Advanced Energy Communities", GFO-15-312, https://www.energy.ca.gov/contracts/GFO-15-312/.

- Reduce energy costs by continuously achieving or approaching zero net energy.
- Are financially attractive for developers, homebuyers, homeowners, and renters.
- Minimize the need to new or upgrading energy infrastructure.
- Support grid reliability and resiliency through the incorporation of energy storage.
- Align with and support state environmental, renewable generation, and local capacity requirements.
- Use smart-grid technologies throughout the community.
- Can be replicated and scaled-up throughout the state to reduce costs.

Designing an effective AEC requires continuous consideration of technical, economic, and financial interactions. For example, adoption of LED lightbulbs will improve lighting efficiency, but will also reduce waste heat that may offset the amount of heating required to maintain comfort within a house. The reduced lighting load also reduces the potential benefit of installing onsite renewable generation and energy storage since electric demand is decreased. Meanwhile, the cost impacts of the different measures must be considered, as well as the financial mechanisms through which they are purchased. Prior to this project, there was a lack of tools or design methodologies that could be used to optimally design an AEC while considering the necessary technologies and the economic and financial implications.

The goals of this project were to:

1. Develop extensible tools that can be used to plan and design an integrated set of energy technologies that convert a community into an Advanced Energy Community.
2. Use these tools to select a set of technologies to convert the disadvantaged Oak View community into an AEC.

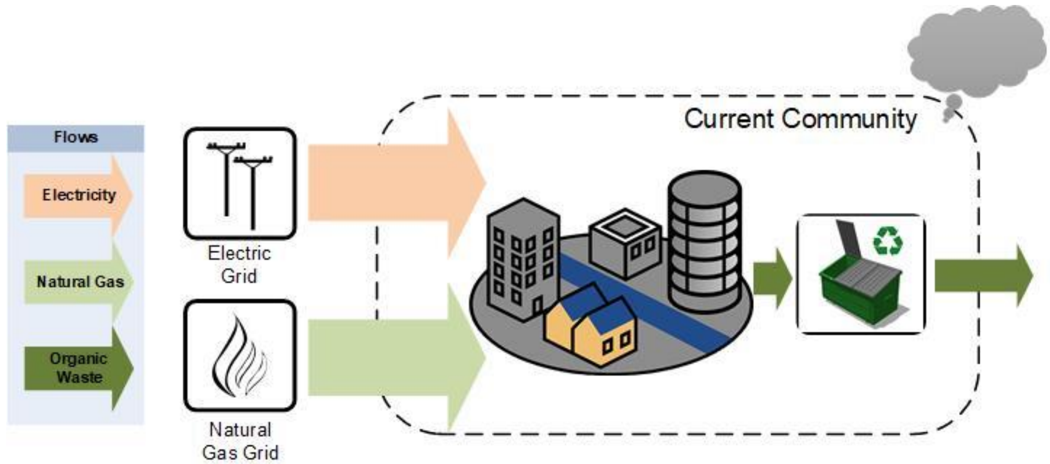
The project team was comprised of the Advanced Power and Energy Program from the University of California, Irvine, the City of Huntington Beach, the National Renewable Energy Laboratory, Altura Associates, Southern California Edison, and Southern California Gas.

Advanced Energy Community Vision

Figure 1 shows energy flows for a typical community (including the current Oak View community) for electricity and natural gas. Energy conversion processes within the community produce local emissions (represented by the grey cloud in the upper right corner of

Figure 1) due to natural gas combustion, but also emissions located at the power plants needed to supply the community with energy. Garbage and waste generation results in a stream of trash and recyclable materials flowing out of the community that is either separated and recycled or dumped into a landfill.

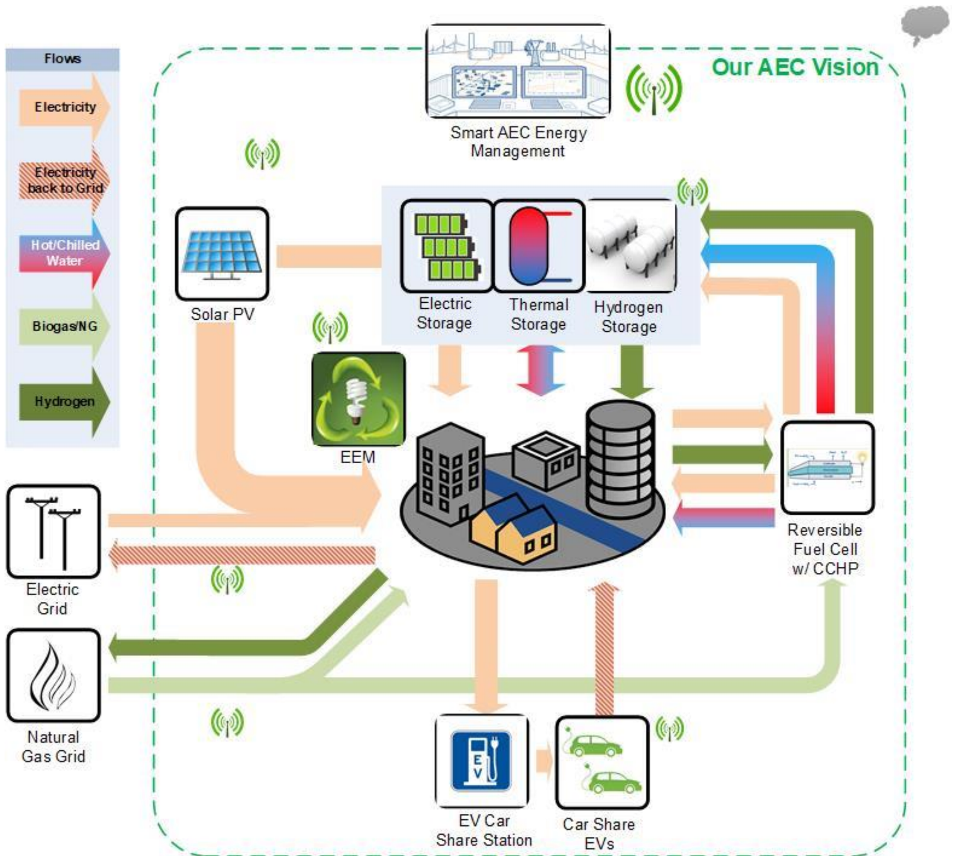
Figure 1: Energy Flows in Typical Community



Source: University of California, Irvine

Figure 2 depicts the conversion of the community into an AEC. Buildings are upgraded with EE measures, solar generation is installed and paired with electrical energy storage (EES), and conventional vehicles used for typical driving needs (going to work, school, or local shops) have been replaced with electrical vehicles.

Figure 2: View of an Advanced Energy Community



Source: University of California, Irvine

In addition, a high-efficiency fuel cell is installed to provide additional electricity to the community, and exhaust from the fuel cell can provide heating to the community. As an added benefit, the fuel cell can be operated in reverse so that excess solar energy not used by the community can be put into the fuel cell with water to generate hydrogen (referred to as power-to-gas). This hydrogen can then be used in place of natural gas, stored for later use, or injected into the local natural gas pipeline.

The AEC also includes advanced energy management controls using extensive energy use monitoring equipment and load controls. This better enables the matching of electrical demand to production, allowing for operation that not only optimizes community benefits but also provides benefits to the local utility, surrounding communities, and California ratepayers.

This project examined a wide array of technologies. In general, any technology, method, or upgrade that reduces the use of energy at the point of use is considered to be an EE or energy conservation measure (ECM). Any technology that can generate electricity at the point of use (such as solar PV), or can be used to store electricity or other type of energy (such as EES, cooling storage through the use of a cold water tank, or the storage of fuel produced onsite), is considered to be a distributed energy resource (DER). Technologies that allow for any community loads to be augmented are known as demand response. Finally, any technologies that can be installed on the electrical utility infrastructure to better support electrical grid operation and enhance communication between the utility and onsite electricity usage and generation is known as smart grid technology.

The technologies shown can lead to the creation of an AEC when optimally integrated into a community. Most importantly, by using advanced control technologies, the increased system flexibility created through the use of generation within the community can be used whenever necessary to improve local grid performance, leading to benefits to the surrounding communities. By designing the AEC using a suite of disparate technologies, the resulting community will be flexible, capable of changing behavior as outside forcing factors change.

Oak View Community

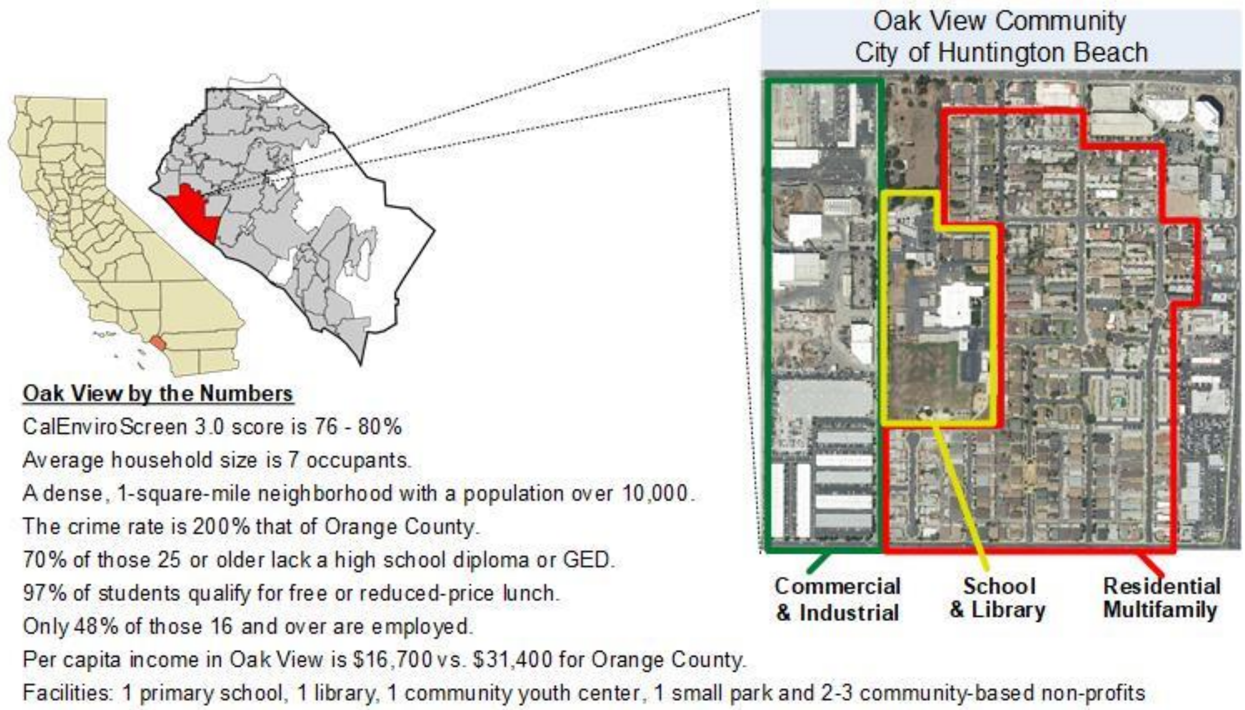
This project was conducted in the Oak View community located in the City of Huntington Beach. Extensive information was gathered about the community prior to any design work, including both technical and other data, such as socioeconomic information which could lead to including systems and technologies that might otherwise be overlooked. Figure 3 shows an aerial image and map location of Oak View within California, along with some statistics about the community.

The Oak View community has a score of between 76 and 80 percent[3] on the CalEnviroScreen 3.0 tool, used to identify disadvantaged communities throughout the state. In addition to qualifying as a disadvantaged community according to CalEnviroScreen standards, the Oak View community also contains a wide variety of buildings (Figure 3) within the commercial and industrial sector (green box), the school and educational sector (yellow box), and the residential sector (red box). More information on types of buildings within the community is in

Figure 4. Within the commercial and industrial sector, there is a large waste transfer station that is owned by Republic Services. Zodiac Aerospace, an aircraft parts manufacturer, lies directly south of Republic Services. Storage and distribution warehouses lay to the south of Zodiac, and small commercial stores are at the northern end of the commercial and industrial sector. Within the educational sector, there is the Oak View elementary school, the Oak View Family Resource Center, the Oak View Branch Library, and multiple different classroom facilities. The residential sector is primarily multifamily complexes with a mixture of for-profit and nonprofit property owners. One of the largest for-profit property owners operates the Solteros Apartments. The nonprofit housing groups operating in the area include the Orange County Community Housing Corporation, American Family Housing, and Jamboree Housing. These nonprofits own properties throughout the Oak View community, but the majority of properties are located within or around the highlighted nonprofit area shown in

Figure 4. In total, there were 311 buildings that were included in this study.

Figure 3: Snapshot of Oak View Community in City of Huntington Beach



Source: University of California, Irvine

Figure 4: Oak View Community Building Groups

Source: University of California, Irvine

Report Outline

The purpose of this report is to describe the progress made towards AEC design tools and how the project team applied those tools to develop a design for the Oak View community. The report is organized as follows:

- Chapter 2 describes the set of objectives and tasks established to achieve the project goals.
- Chapter 3 describes the project outreach that occurred throughout the entire project.
- Chapter 4 summarizes the tools developed for designing and operating an AEC.
- Chapter 5 summarizes the financing structures that were evaluated for the AEC.
- Chapter 6 details the methodology developed for designing a generic AEC.
- Chapter 7 details the methodology and modeling done to design an optimal AEC for the Oak View community.
- Chapter 8 describes the design developed for the Oak View AEC.
- Chapter 9 summarizes the results and lessons learned for the project.

CHAPTER 2: Project Objectives

To accomplish the project goals, the project team established a series of objectives. These objectives fall into three groups, described below: 1) model development, 2) AEC design, and 3) community outreach. The order does not indicate the order in which these were performed; community outreach was the first step taken by the team and continued beyond the end of the project.

Model Development Objectives

To effectively design an AEC, the team needed to develop new tools. The reasoning behind the necessity for each tool is provided.

- Community energy simulation tool: To predict the impact of EE measures across the community, the team needed to understand individual building energy behavior. Ideally, an AEC design team should be able to capture energy usage data for each build. Doing so, however, typically requires extensive interaction between utility ratepayers in the community, local utilities, and project partners. Considering the need to also be able to predict the impact of EE and ECM, it is more beneficial to develop tools that can predict the energy use of the current community as well as energy use after EE and ECM implementation. To do this, building energy simulation tools that predict energy usage based on predicted occupancy patterns, physical processes (sunlight entering through windows, interior heating from waste heat produced from a hot light bulb), local weather, building geometry, and building material properties must be modified to expand beyond the scope of a single building to capture the energy use within a community.
- Energy management simulation tool: Once energy usage within a community has been developed, the design team must determine how best to procure and manage energy for the community, whether through the purchase of energy from the utility or from integration and operation of DER. DER technologies include solar PV panels, reversible fuel cells, (EES, and controllable loads to be paired with DR. Optimal decision making at this level is critical to ensure both economic and technical feasibility. To capture this, a series of models that capture the critical components must be developed to ensure optimal selection and operation of any DER technologies, as well as to ensure the technical feasibility of integrating these technologies into Oak View and the surrounding communities.
- Financial model: Even after optimal selection of technologies has been determined, the financial mechanisms through which each piece of equipment is purchased must be viable. To ensure financial viability, a financial model that considers relevant community members must ensure that the appropriate members are providing sufficient funds to

lead to AEC technology integration, and then ensure that the benefits are distributed to the relevant parties as agreed upon during the AEC design phase.

Advanced Energy Community Design Objectives

A design framework is essential to effectively design an AEC. The following objectives guided the team's efforts from the design of the framework and through AEC case studies to the final design:

- Establish an AEC design framework: As the tools are developed, a framework through which they are applied must be established. Considering the wide array of available renewable and sustainable technologies, the framework must establish a process through which different design scenarios are considered equally.
- Develop AEC case studies: As the AEC design tools are developed, different combinations of AEC technologies will perform differently. To select which group of technologies should be used in the final design phase, multiple case studies must be performed to allow AEC designers to select the best combination of technologies.
- Select final AEC design: Once the case studies are performed, the final set of AEC technologies can be determined leading to development of a refined and final AEC design.

Oak View Community Outreach

The success of AEC design depends on community acceptance. If the local community rejects the design for any reason, then implementation is guaranteed not to occur regardless of potential benefits. To ensure community acceptance, widespread outreach must occur to ensure that the community is educated about the benefits of the final plan, and to enable the community to benefit from AEC implementation. As a result, the project team established the following objective to achieve the outreach goal:

- Develop and implement an AEC outreach plan: To accomplish this, outreach was made to all members of the Oak View community. The outreach plan also created the basis for continued outreach during the implementation phase of the project.

Tasks

To achieve the objectives of this project, the team established the following tasks:

- Task 1, General Project Tasks: In this task, all of the project team members worked together to complete the tasks specified in this list. This included reporting on the progress and results of each task to the Energy Commission.
- Task 2, Develop AEC Design and Planning Tool: This tool was intended to provide insight and recommendations on various integration and deployment options for the community. Information gathered during outreach activities was used as inputs into the model.

- Task 3, Develop Smart Community Microgrid Energy Management Model: This model selected, simulated, and evaluated the impact and performance characteristics of the DER selected for the AEC.
- Task 4, Carry Out Case Studies on Various Integration Designs: This task led to developing an optimized roadmap for the technical and financial development of the AEC. The design effort included a combination of EE and DER measures. These case studies quantified the economic and environmental benefits and technical performance of the proposed technology mixes.
- Task 5, Propose Master Community Design: Using the case studies, the team proposed a master community design that followed a generic master community design method developed to lay out the design process for an AEC.
- Task 6, Develop Financial and Business Models: A financial and business model was developed to support the master Oak View AEC design. The model showcased optimal financing and partnership mechanisms that would benefit all relevant stakeholders.
- Task 7, Develop Outreach Strategy: This strategy was used to educate the Oak View community, including residents, the building industry, government agencies, and other interested parties. The strategy also provided educational benefits to local school children, professional training opportunities, and job creation within the community with an emphasis on green energy job training.
- Task 8, Evaluation of Project Benefits: In this task, the project team worked collaboratively to deliver all required products.
- Task 9, Technology and Knowledge Transfer Activities: The project team developed a plan to make available the knowledge gained, experimental results, and lessons learned to the public and key decision makers.

These tasks did not proceed in sequential order; outreach to the community began prior to the development of the tools developed through Tasks 2 and 3 since it was critical to establishing a relationship with the community and to gather immediate feedback on the community's interests.

CHAPTER 3: Community Outreach

This chapter describes the community outreach that occurred throughout the Oak View community, as well as in the extended business and government communities.

Digital and Print Media

The Oak View community is home to a largely Spanish speaking population. As a result, all media resources must be available in both English and Spanish to ensure viable communication. Additionally, the project team distributed media via different avenues that best served the community's needs. Methods of distribution included flyers circulated through the Oak View Family Resource Center and Oak View Library branch, and by the resident code enforcement officer who regularly patrols the neighborhood. The team also distributed information digitally through email to previously engaged community members who had participated in the Huntington Beach Police Department Citizens Academy, and to the Family Resource Center's class attendees and users.

Website Development

The project team developed the AEC webpage after initial outreach with residents indicated an online resource would help residents in and outside of Oak View better understand the project. The page is hosted on the City of Huntington Beach's website in the Sustainable Huntington Beach section, which is often used by residents looking for more information about the city's programs to promote environmental sustainability. The section highlights current projects and programs and provides resources for residents.

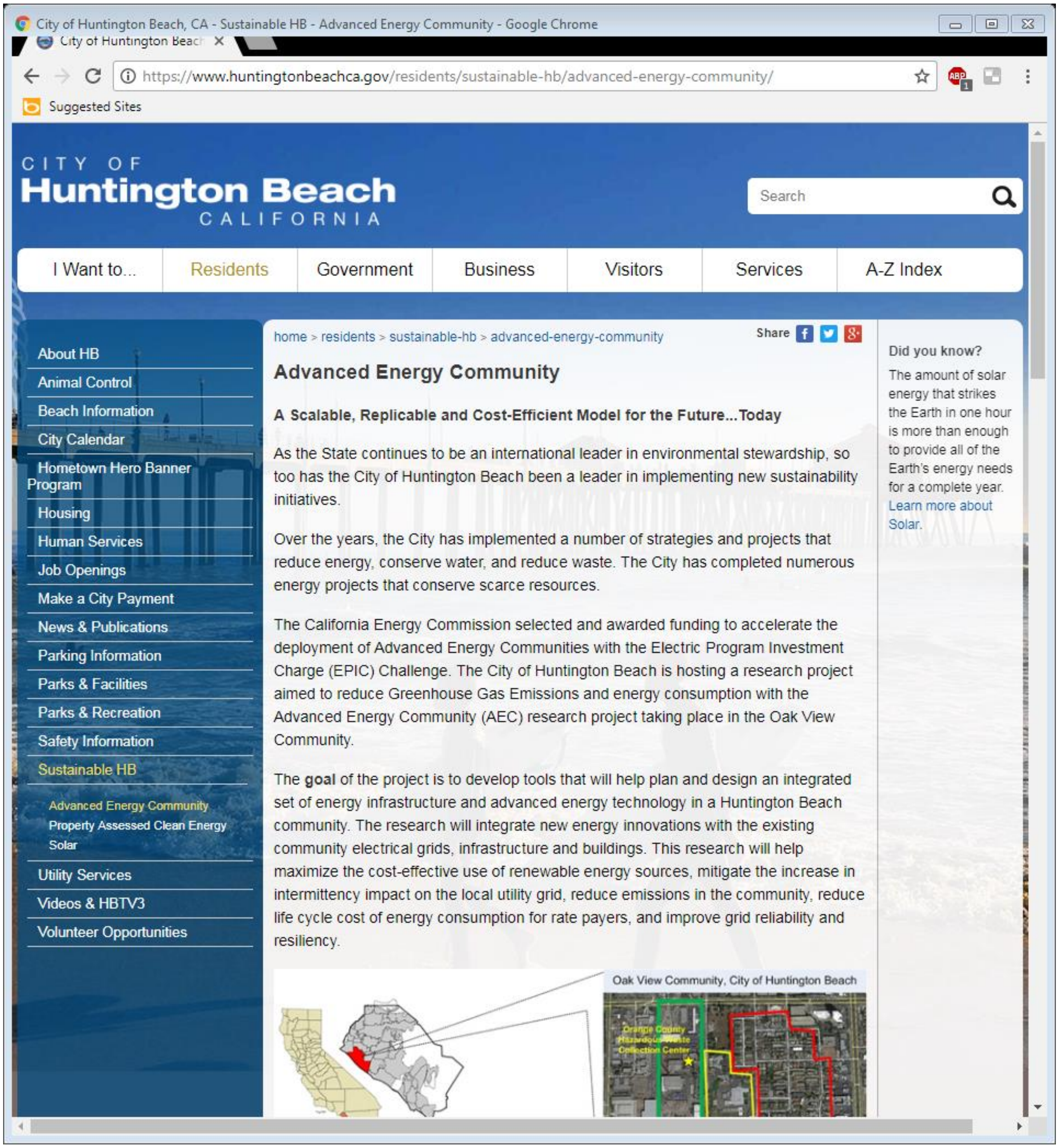
The AEC webpage provides an overview of the Oak View community project and describes the roles of all project partners. Outreach also indicated that residents wanted a place to easily find contact information regarding the project, so the team included contact information for the city, the University of California Irvine, and Altura and Associates as well as links to all partner websites. To increase the page's accessibility, the team created a shortened URL (huntingtonbeachca.gov/AEC) and implemented refined meta-descriptions and keywords to allow search engines to better index the page for discovery.

Figure 5 shows a screenshot of the project website.

Lotería Card Design

Lotería is a bingo-style game with icons and words that is very popular in Mexico and in Central America. The project team adapted the game to use icons related to the AEC as well as EE measures. Participants played the EE version of Lotería at the energy workshop that is described later in this chapter. Project partners participated in the game and engaged the audience on the information on the different cards to discuss the benefits of each technology. The purpose was to help participants retain information learned in the workshops and enable them to teach family, neighbors, and other residents in the community about EE measures in their homes. The game was distributed to workshop participants to play at home, and was also distributed to the Oak View Family Resource Center and the city's Police Department Spanish Citizens Academy so that the game would continue to be available.

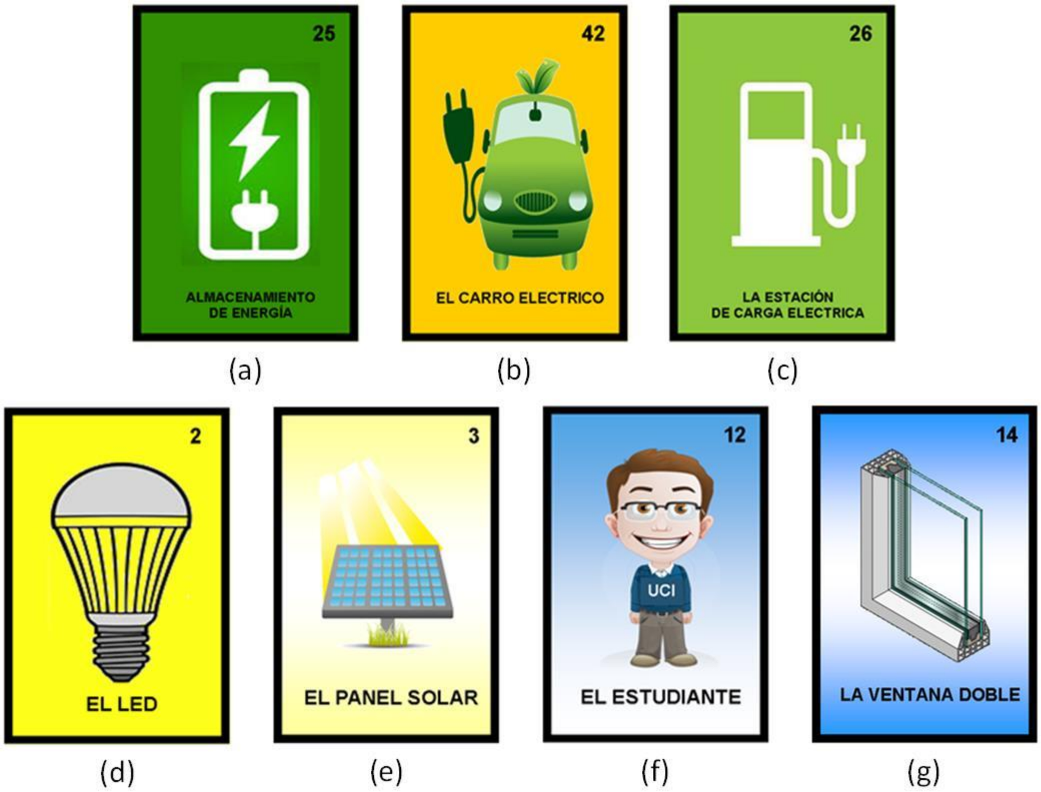
Figure 5: Advanced Energy Community Project Webpage



Source: City of Huntington Beach

An unexpected benefit of the game was that it also encouraged attendance. Participants were immediately intrigued by the idea of the Energy Efficiency Lotería and looked forward to being rewarded with a tangible final product that they could use with children in their families.

Figure 6: Novel Loteria Cards to Help Educate the Community about the Advanced Energy Community Project



Cards include (a), electrical energy storage, (b) plug-in electric vehicle, (c) electric vehicle charging station/equipment, (d) light emitting diode (LED) lightbulb to represent energy efficiency, (e) renewable generation in the form of a solar photovoltaic panel, (f) student researchers at UCI who are assisting with the AEC design process, and (g) double paned windows increase insulation

Source: University of California, Irvine and City of Huntington Beach

Community Fliers and Handouts

Figure 7 through Figure 9 show various flyer designs the project team created to raise community awareness about the AEC project and invite residents to classes on the subject. The flyers were produced in both English and Spanish. Figure 10 shows the handout for businesses in the community.

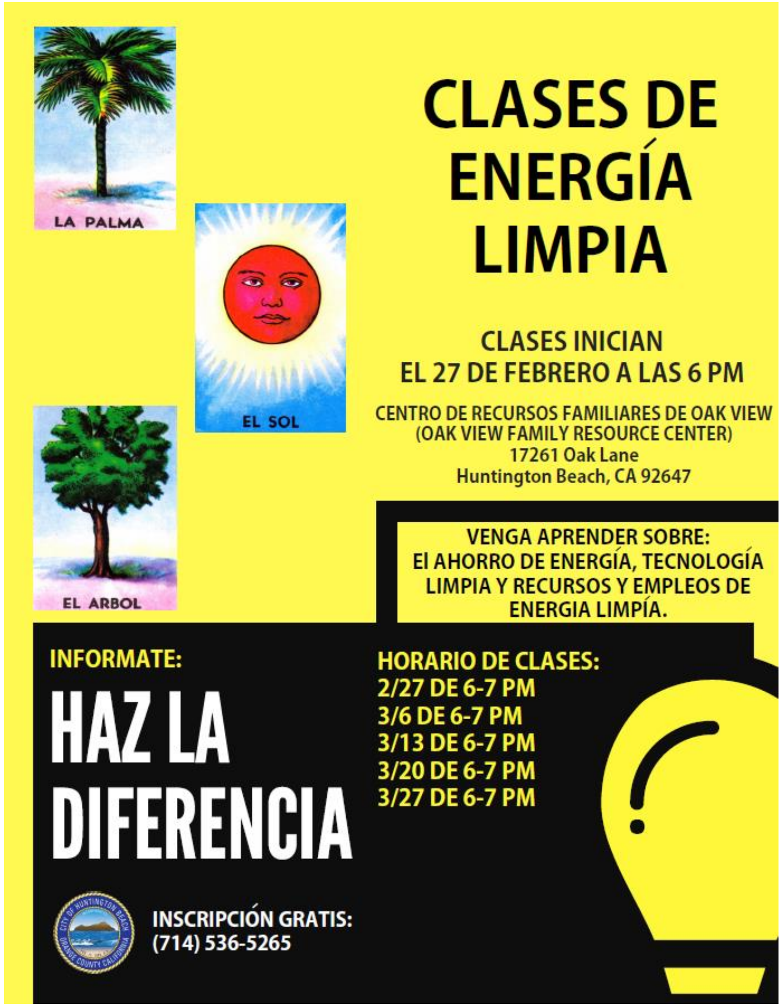
Figure 7: "Green" Handout on Potential Advanced Energy Community Benefits

Source: City of Huntington Beach

Figure 8: Lotería Handout describing Potential Advanced Energy Community Benefits

Source: City of Huntington Beach

Figure 9: Handout for Educational Classes on Advanced Energy Community Project



Source: City of Huntington Beach

Figure 10: Handout for Community Businesses on the Advanced Energy Community Project

Source: City of Huntington Beach

Energy Education

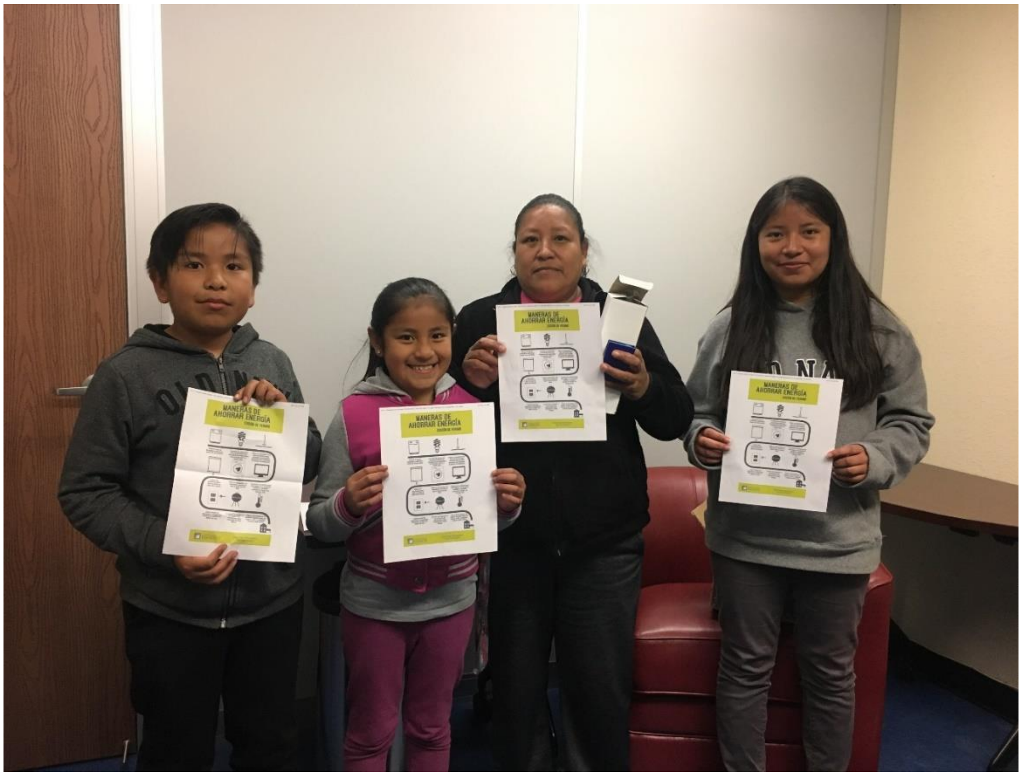
Two separate education pathways were developed during the project, the first aimed at introducing the general community to the project and the second to provide energy education to local children.

Adult Workshop

The purpose of the adult workshop was to engage all members of the community in the project. The workshop used the partner resources and connections to educate the local population about available EE and low-cost utility energy options, describe the current AEC project, and solicit feedback from participants on technologies or improvements they wanted to see in their community. The workshop took place over six weeks, with each week having a separate topic and the final week culminating in the playing of the Lotería game described earlier.

Figure 11 shows a family that participated in the workshops and won a contest prize.

Figure 11: Workshop Participant Contest Winner and Family



Source: City of Huntington Beach

Youth Educational Plan

The Out-of-School Time Energy Program (OSTEP) launched at two sites, the Oak View Library and the Oak View Boys and Girls Club. Both sites are in the heart of the community and widely used by community members. The library offers a daily homework club where students from the local elementary school and middle school gather to work on their assignments, and features workstations and computers to access educational resources and games. The Boys and Girls Club is located within the Oak View Family Resource Center and offers enriching activities during after-school hours.

The Oak View Library and the Oak View Family Resource Center are pillars of support within the community and were ideal launch sites for the youth education program. Children who attended the OSTEP program at these sites gained knowledge of energy sources, how energy impacts their life, the importance of creating EE systems, and jobs related to the energy sector. The Advanced Power and Energy Program team also incorporated a fuel cell and alternative generation lesson that was developed at UC Irvine.

The OSTEP program was offered Wednesday afternoons at the Oak View Branch Library starting on April 11, 2018. The program included 10 sessions and concluded on June 20, 2018. The OSTEP program ran from April through June at the Boys and Girls Club as well. Elementary and middle school children were invited to experience hands on science, technology, engineering, and math lessons through the OSTEP program. The lessons were designed to align with Common Core and Next Generation Science Standards and focused on environmental and sustainability concepts through hands-on training that used critical-thinking and problem-solving skills to address challenges and come up with solutions. The Boys and Girls Club used its internal staff, and the library used an established network of volunteers, to implement the OSTEP program. The program at the library was led by a graduate student from California State University, Fullerton. OSTEP outreach flyers are included in Appendix A.

Lessons

- Energy Vampire Hunt: Students planned and carried out an investigation of "energy vampires" using a watt meter to measure the energy consumption of different electrical devices. Students collected and charted the data from their investigation and calculated how much money could be saved by unplugging energy vampires.
- Fuel Cells (UCI Lesson): Students from UC Irvine hosted a session and demonstrated how a fuel cell works and how it would relate to the project. The interaction between the students and program participants was highly beneficial because it showed them things they otherwise would not have seen and introduced them to a potential field of study they could directly relate to. Students produced hydrogen from water using pencils, paper clips, and a small 1.5 volt battery, used hydrogen to power a small fuel cell to turn a fan, and built an electric motor using paper clips, a 1.5 volt battery, a copper wire hoop, and a magnet.
- Got Water: Students investigated how increased human water consumption affects the supply of available water. Students learned about the importance of conserving water, efficient water transportation, and the water-energy nexus.
- Potential, Potential…Kinetic: Through kinesthetic learning, students distinguished between examples of kinetic and potential energy. When playing a game students communicated and applied knowledge about renewable and nonrenewable energy resources and EE.
- Water-Energy Nexus: Students designed and constructed a model to engineer a solution for water-related problems in California. Students presented their designs to the class to collect feedback and suggestions from each other.
- Solar Oven: Students designed and built a model to examine how sunlight can be converted to thermal energy by constructing a solar oven. Students then described uses of thermal energy and explained how different types of energy (thermal, radiant, and light) are harvested from the sun. During this activity, the students used their solar ovens to make nachos with no energy input other than sunlight.

- Energy Melody: Students analyzed the diagram of a power plant and determined what forms of energy are involved in each step of the electrical generation process. Students also applied the concept of energy transfer and transformation to areas across the site. Students learned and performed a song using movement to demonstrate knowledge and teach others about the electrical generation process.
- Trash Art: Students examined how a lot of energy are required to manufacture, fill package, and ship plastic bottles for human use and how long it takes for plastic bottles to reduce waste, energy, and consumption of resources; create portable, mini gardens and learn about plant growth.
- Sun Power: Students investigated ways to capture light energy from the sun and then applied the knowledge gained about solar energy to develop an action plan for their homes or classrooms to harness the sun to reduce the use of artificial light.
- Hydrating Californians: Students built and used a model to demonstrate how energy is used to transport and purify water to consumers in California. Students were able to explain the water-energy nexus and identify challenges of moving water from its sources to faucets.
- Life of a Water Bottle: Students made "slime" and discussed how much energy the process of manufacturing a plastic water bottle consumes. Students were then able to explain how using fewer plastic bottles saves the Earth's natural resources.

Workforce Development Plan

The Future of Green Collar Jobs in California

Three bills in California are driving career growth in the energy sector. The first is Senate Bill 350 (de León, Chapter 547, Statutes of 2015) [1], which requires California to double statewide EE savings in electricity and natural gas uses by 2030. The second is Senate Bill 100 (de León, Chapter 312, Statutes of 2018), which accelerated and increased renewable energy targets to 50 percent by 2026 and 60 percent by 2030. The third is Assembly Bill 802 (Williams, Chapter 590, Statutes of 2015)[4], which mandates a new statewide building energy use benchmarking and public disclosure program. Under AB 802, the electricity and gas corporations will continue to provide financial incentives to their customers who increase the EE of existing buildings.

Careers in both EE and renewable energy are expected to flourish under these regulations. According to the Bureau of Labor Statistics, careers in wind and solar are projected to grow the fastest over the coming decade [5], and employment opportunities for solar PV installers are expected to grow 105 percent between 2016 and 2026. According to an E4 "The Future" study[2], California is now leading the nation in jobs related to EE with an estimated 321,000 jobs available in that sector alone. Orange County residents currently hold 28,120 of those

[2] E4TheFuture, "Energy Efficiency Jobs in America,"2018, https://e4thefuture.org/wp-content/uploads/2018/09/EE-Jobs-in-America-2018.pdf.

positions. The workforce development plan created for the Oak View community will prove to be a valuable resource to any individuals looking to enter into this growing industry.

Green Collar Job Development in Oak View

The project team created a workforce development plan to facilitate access to the green collar job market in the Oak View community. The Oak View plan provides information to community members on education and certification programs offered at local community colleges. The skills and knowledge gained from these courses will prepare participants to enter the energy sector.

Since the Oak View population is diverse in age, the goal was to target two separate groups within the population. The first target group was young adults. The team operated under the hypothesis that this group might not need to support a family, might qualify for certain types of financial aid, and would be able to continue school for an extended period of time. The team researched green collar related courses and program offerings at local community colleges to support job development in this segment of the Oak View population. The second target group was assumed to be supporting themselves or family members and therefore be unable to spend extended periods of time in the classroom. To facilitate career development in this group, the team focused on green collar trades and apprenticeships which could provide wages during training that could be used to support the individual and their family. Note that neither group would be precluded from pursuing any career path that is outlined in the workforce development plan. Instead, the team attempted to anticipate different focus groups that would reach the largest number of individuals within the community.

The goal of the workforce development plan was to create literature that communicated valuable information about the various school and trade options available to Oak View residents. The team modeled this work after pamphlets generated by the Emerald Cities Initiative in Los Angeles [6], which provides a book with information on different local trades including required skills, wage levels and benefits, education and training requirements, and contacts for more information. The goal was to create a booklet with similar information for green collar trades that would capture positions with low barriers to entry as well as positions that require higher education. Phase II of the workforce development plan is expected to be rolled out to the community during Phase II of the project.

Overcoming Barriers to Work

The team understands that there are barriers for some community members that can increase the difficulty of joining the green collar workforce. To overcome these barriers, the team worked on combining career information with supporting services. The list showcases the various sections of the Comprehensive Oak View Workforce Development Plan:

- Career list: Highlights 40 green collar career options including: descriptions of work, typical activities, annual projected job openings and wage ranges throughout California and the United States, education required to start, desired experience, and desired skills.

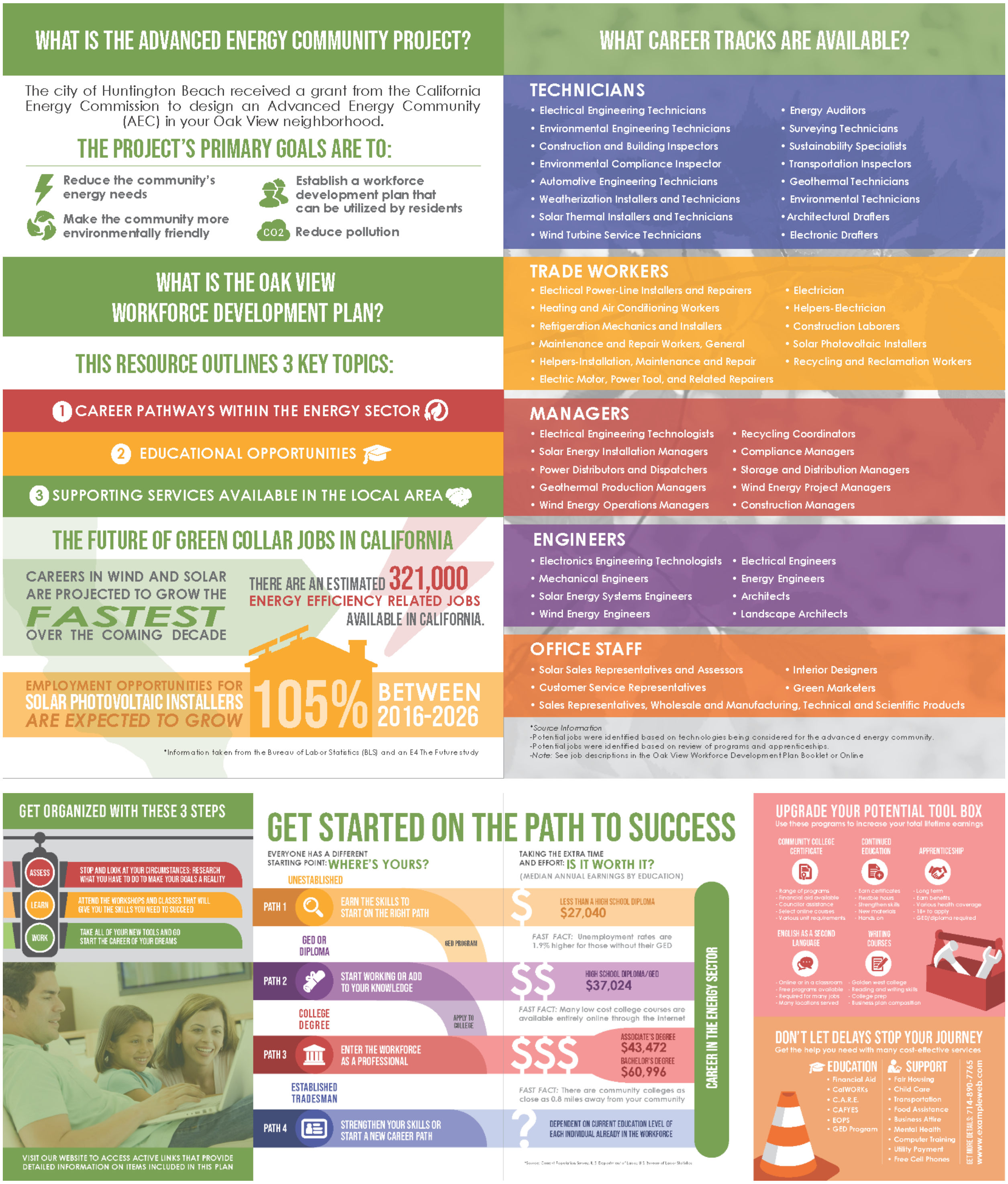
- Community college programs: Showcases 43 local community college programs offered within 15 miles of the community.
- Apprenticeship offerings: Provides information on 6 local apprenticeship programs.
- Continued education: Provides resources for those currently working in the energy sector who wish to expand on their skill sets.
- Soft skills: Provides classes on resume building, interviewing, networking, public speaking, entrepreneurship, business planning, money management, time management, organization, punctuality, creativity, marketing, customer service, and computer literacy courses.
- Supporting services: Provides information on counseling, mental health services, childcare services, transportation services, utility assistance, food assistance, clothing assistance, housing assistance, and assistance provided through local community colleges.
- Financial aid services: Provides information on Federal and local aid.
- CalWORKs services: Provides information on work study programs offered at local community colleges.
- English as a second language and writing: Provides information on programs designed to prepare individuals for college level courses.
- High school and general education development: Provides information on programs offered in the local area.

By combining this information with career information, the team believes that realistic pathways can be built to facilitate the development of a green workforce within the Oak View community.

Dissemination Plan

The team interacted with the Oak View Branch Library to establish an area within the community where career support and development could occur. In addition, the team reached out to the Oak View Family Resource Center to garner their support and assistance with establishing and maintaining the workforce development plan and distributing the workforce development pamphlet, shown in Figure 12. Finally, the information was disseminated to the community through the various outreach mechanisms, including the adult workshop discussed earlier. Additional outreach will occur during Phase II of the AEC project.

Figure 12: Interior of Workforce Development Pamphlet which Features Pathways to Potential Green Jobs



Source: City of Huntington Beach

Other Outreach Activities

Oak View Task Force Meetings

The Oak View Task Force was established to "…facilitate communication between City staff and the various agencies that serve the Oak View Community, the City formed the Oak View Task Force.[3]" Participants who provide regular updates include the Oak View Renewal Partnership, the Oak View Elementary School, the Oak View Family Resources Center, the Oak View Branch Library, the Huntington Beach Police Department, and Huntington Beach Code Enforcement, as well as other interested citizens and organizations. Meetings occur quarterly in either the Oak View Family Resource Center or an Oak View Elementary classroom. The project team routinely attended the meetings where they presented updates on the team's progress. This interaction increased the visibility of the project with different organizations within the Oak View community, and allowed for continual interaction between the project partners and key groups that are critical for maintaining outreach, such as the Oak View Branch Library.

Newspaper Articles

The project was highlighted in the following publications:

- Orange County Register (December 4, 2017): "Rewiring the State will Happen One Neighborhood at a Time"
- Daily Pilot (December 22,2017): "UC Irvine and Huntington Beach partner for energy efficiency in Oak View community"

Conferences/Peer Sharing

The work done on this project should be shared so that other communities can take away best practices, lessons learned, and outreach methods to use in their own communities. The project has been shared at the following conferences/meetings:

- October 13, 2016 – Clean Tech OC Presentation on the Advanced Energy Community at the Annual Conference joint presentation by the City of Huntington Beach, Altura Associates, and UCI.
- November 2, 2016 – City of Huntington Beach presentation to Chapman University on Sustainability Programs including the Advanced Energy Community project.
- November 2, 2016 – City of Huntington Beach presentation to the City of Huntington Beach Chamber of Commerce on Sustainability Programs including the Advanced Energy Community project.
- February 28, 2017 - City of Huntington Beach presentation to the Electric Power Research Institute (meeting held in Newport Beach, CA) on Sustainability Programs including the Advanced Energy Community project.

[3] Taken from: https://www.huntingtonbeachca.gov/government/boards_commissions/Oakview-Task-Force.cfm.

- March 6, 2017 – City of Huntington Beach presentation to Southern California Gas Company Gathering of the Green Teams Using Storytelling to Convey a Sustainability Strategy.
- April 12, 2017 – City of Huntington Beach presentation to the University of California Irvine, USGBC, and AIA Sustainability Symposium about the City's Sustainability Programs including the Advanced Energy Community project.
- October 2, 2017 – City of Huntington Beach presentation to the Southern California Edison All Partner's Meeting on the City's Advanced Energy Community project.
- October 19, 2017 – Sustain OC Presentation (formerly Clean Tech OC) on the Advanced Energy Community at the Annual Conference joint presentation by the City of Huntington Beach and UCI.
- February 5, 2018 – Huntington Beach Coordinating Council – presentation to volunteer group (multiple groups represented Kiwanis, Land Trust, HB Huddle Environment, etc.) on City sustainability programs including the Advanced Energy Community.
- March 1, 2018 – City of Huntington Beach presentation on panel at the Climate Leadership Conference on the City's Advanced Energy Community (outreach to disadvantaged populations).
- April 18, 2018 – UCI, City of Huntington Beach, and Altura presented the current progress of the AEC project to the Local Government Commission.

Non-Residential Outreach

Recognizing the presence of the Oak View Elementary School and numerous local businesses in the community, the project team engaged with the various community members located outside of the residential areas. The general approach for garnering school and business support was to describe the potential benefits of a successful AEC implementation but also offer professional energy audit services provided by Altura Associates. These efforts resulted in support from the Oak View Elementary School and the Ocean View School District. The team continued to apply this approach to garner full-scale support from the local businesses. By working with the city's Office of Business Development and Business License division, UC Irvine and Alturas Associates representatives were able to make contact with non-profit housing and commercial and industrial businesses to further discuss the benefits of the project and potential partnerships.

CHAPTER 4: Design and Operation Tools

Tools needed for this project included a community-scale energy simulator and energy management model. The simulator was accomplished by development of URBANopt, which was based on existing building energy simulation tools. The energy management model was developed through this project and consists of multiple sub-tools used to determine optimal energy procurement, electrical energy flow through the local utility grid, and community renewable fuel potential.

URBANopt – Community Scale Energy Simulation

Background

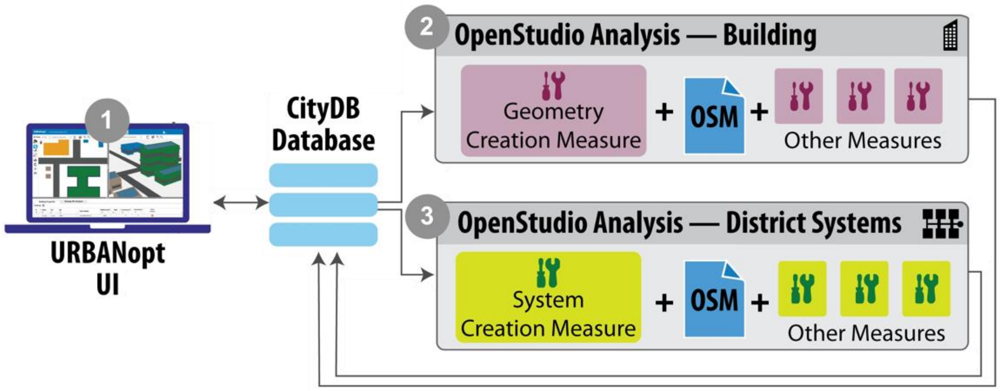
NREL's contribution to the project was URBANopt, an open source application that builds on the United States Department of Energy EnergyPlus simulation engine and OpenStudio[4] building energy modeling platform [7–9]. URBANopt follows the OpenStudio design philosophy of enabling the development of third party user interfaces (UIs) that interoperate with a powerful and extensible computation backend via an application program interface (API). The open source code and documentation that enables such urban-scale modeling application is available at https://github.com/NREL/openstudio-urban-measures, and is built around the concept of small extensible Ruby language scripts that can modify (or create) energy models. These scripts, referred to as OpenStudio Measures, are most often used to represent EE measures. Figure 13 illustrates the URBANopt architecture and is followed by a description of the functionality and relationship between URBANopt UI, an associated project database that stores inputs and results, and analysis workflows that link together OpenStudio Measures to generate building or district system models.

An URBANopt UI may be implemented using any number of software technologies. The UI is primarily responsible for gathering information concerning the community, proposed EE and DER features, serializing project data into an URBANopt compliant GeoJSON (Java Script Object Notation) format, and storing it in a city database (CityDB) for the base case along with any additional scenarios of interest. The UI is also responsible for capturing design scenarios (collections of Measures) and displaying analysis results stored in the CityDB.

NREL has implemented a web-based UI for testing, development, and internal use with integrated CityDB functionality. Specifics of this particular UI are discussed in the context of the project case study presented later in the chapter.

[4] OpenStudio is an open source platform for the creation of desktop applications or web-based services, which enable the rapid creation of energy models for building design, retrofit performance assessment, and load analysis. Models may be built with few or many inputs depending upon the need for precision.

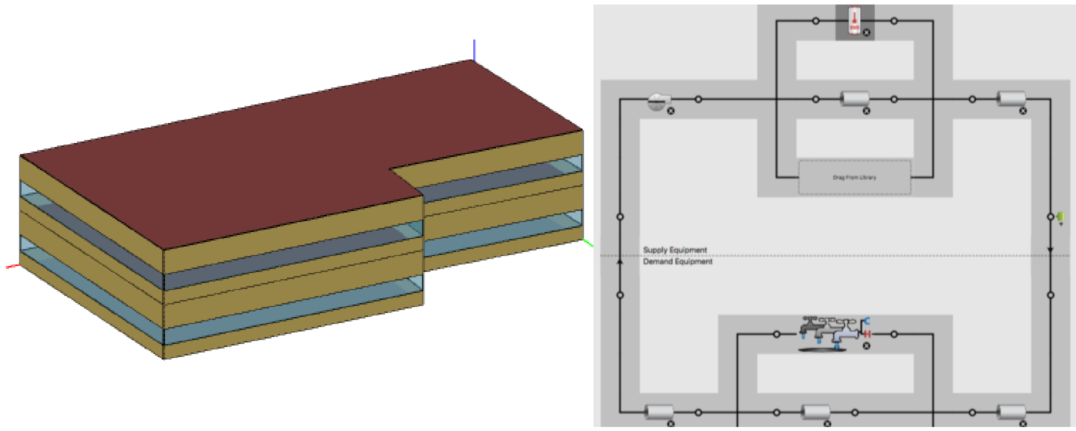
Figure 13: URBANopt High Level System Architecture



Source: National Renewable Energy Laboratory

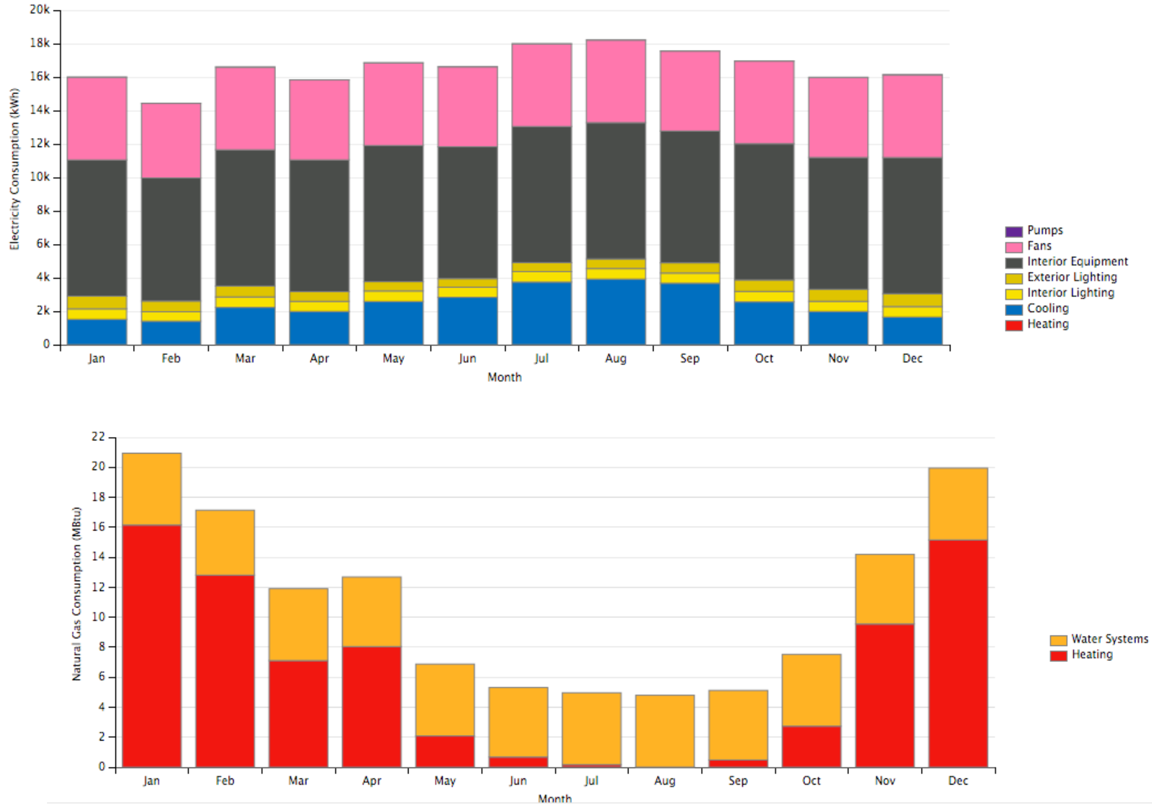
URBANopt's backend for building analysis builds on the OpenStudio Measure concept and OpenStudio Workflow (OSW) files specifying which Measures are to be used, in what order, and with what inputs for a given design scenario. OSWs associated with each design scenario that were specified by the UI and stored in the CityDB are used to automatically construct a building energy model for each structure in the community utilizing high level information such as the building footprint, type, vintage, number of floors, and so on. Figure 14 illustrates a multifamily dwelling model. Each building model is generated using URBANopt input, and fully detailed using modeling assumptions from the OpenStudio Standards library based on ASHRAE 90.1 and California Title 24. Simulations include 8,760 hourly simulation results along with monthly or annual aggregations broken down by end use and fuel type (Figure 15). EE retrofits or rooftop PV may be applied to the base case models by simply adding the appropriate OpenStudio Measures to a scenario's workflow specification. Packages of EE Measures would typically be applied to individual (or all) building models to reflect a particular community design scenario.

Figure 14: Model Details for a Typical URBANopt Multifamily Building Model



Source: National Renewable Energy Laboratory

Figure 15: Monthly Energy Consumption by End Use and Fuel Type for Multifamily Base Case



Source: National Renewable Energy Laboratory

District systems are represented by special-purpose models that are also constructed by OpenStudio Measures based on URBANopt UI inputs. For example, a central chiller plant might be represented by a heating, ventilation, and air conditioning (HVAC) system with loads aggregated from individual connected building loads. Solar PV, battery storage, fuel cells, and other DER systems are captured in a similar manner via the same OpenStudio Measure scripts that might be used to instantiate such systems within a specific building.

URBANopt's backend software manages the automated model creation, simulation, results aggregation, and CityDB storage process via API for each design scenario specified by the URBANopt UI. High level aggregate results are made available within the UI, although an extremely rich set of detailed simulation results for individual buildings or district systems associated with each design scenario may also be retrieved for further analysis.

Smart Grid Community Energy Management Model

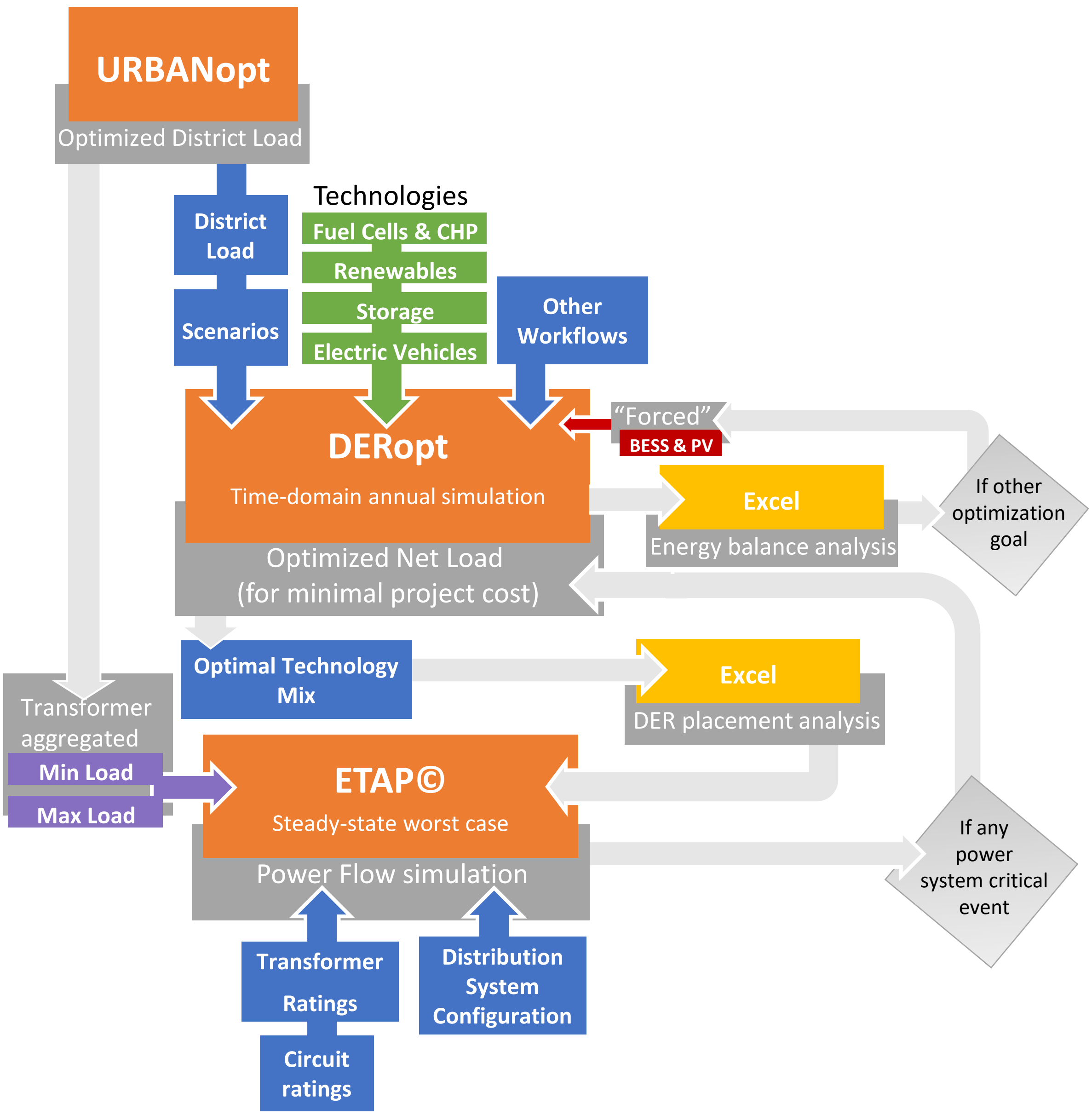
The Smart Grid Community Energy Management Model consists of multiple sub-models and methodologies. When combined, these sub-models and methodologies allow for the AEC designer to determine and understand the best way to procure and deliver energy within the design community. The individual modules are:

1. Maximum solar PV hosting survey

2. Optimal DER selection and placement through the Distributed Energy Resource Optimization model (DERopt)
3. DER operation feasibility using Electric Transient Analysis Program (ETAP) software [10]
4. Renewable fuel evaluation

Figure 16 shows the general workflow with an emphasis on the output of URBANopt being fed into DERopt, with total results directed to the DER feasibility model.

Figure 16: Workflow of Smart Grid Community Energy Management Model



Source: University of California, Irvine

Note that the inputs and results of each modeling component depend on all other AEC design tools. The general workflow through these models is:

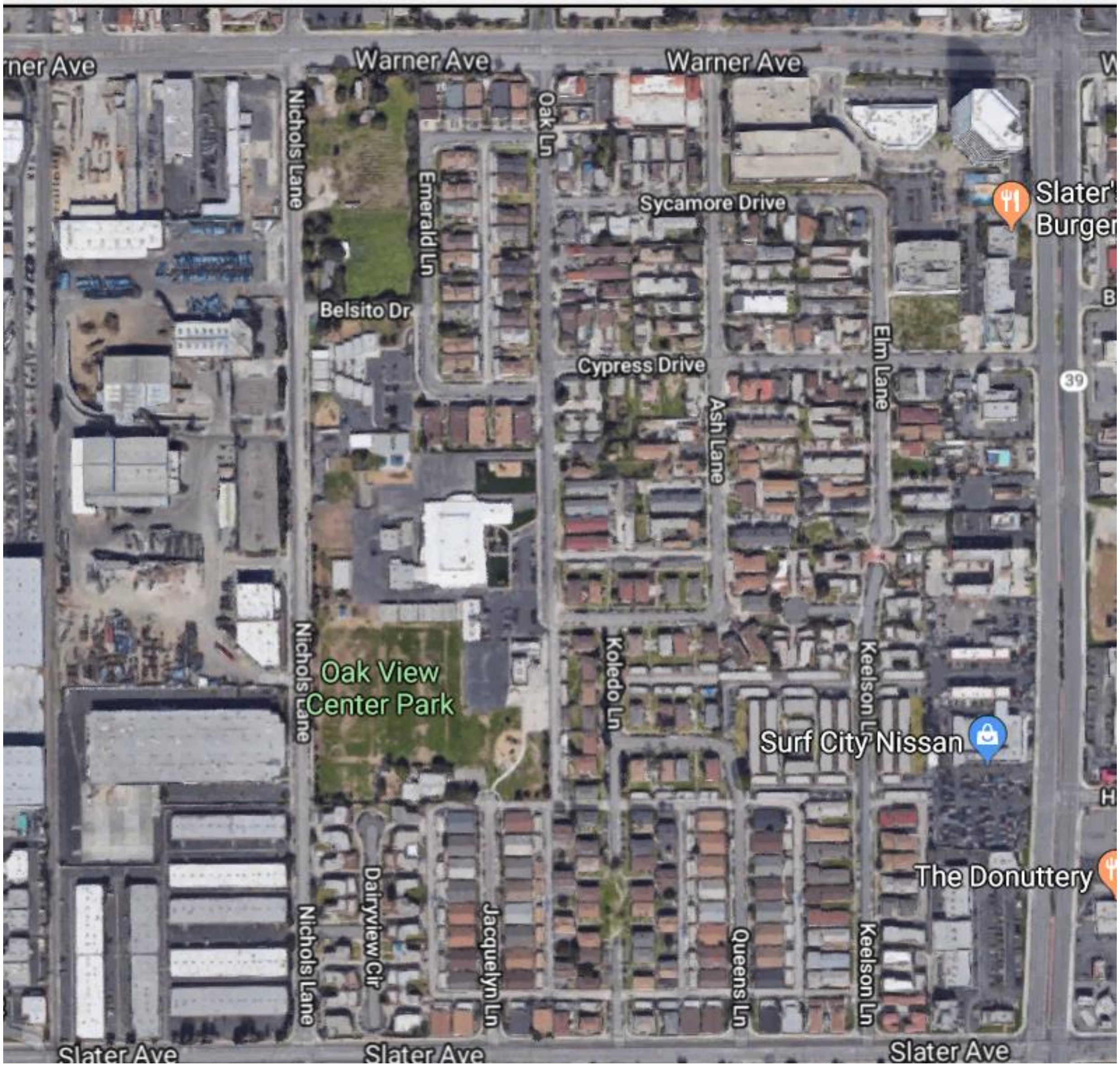
- The URBANopt tool produces energy simulation results for a defined set of EE and ECM technologies.
- These results are then fed into the DERopt tool, which optimally sizes and dispatched DER technologies.
- The DERopt tool uses outputs from the maximum solar PV hosting survey to limit onsite renewable generation from solar PV.
- The output from the DERopt tool is then tested using the DER operation feasibility model, which ensures that the proposed system is able to properly function within the current electrical infrastructure.
- In addition, the renewable fuel potential is also evaluated by examining if excess solar generation were to be used to produce renewable fuels, or if any biodegradable waste were to be directed towards an anaerobic digester for conversion into renewable natural gas.

Maximum Solar Photovoltaic Hosting Capacity Survey

Since an AEC design is defined being capable of approaching or achieving zero net energy (ZNE) operation while also supporting state environmental and renewable generation goals, renewable energy generation is required for successful implementation. Considering the lack of wind resources in most California urban areas [11], the largest opportunity for implementing renewable energy generation in an AEC is through widespread use of solar PV systems. To determine the best mix of generation that includes solar PV, the maximum solar PV hosting capacity for each community must be determined. This can be accomplished by using heuristic methods to predict the available rooftop area for every building. Generating an accurate prediction for a community requires consideration of rooftop geometry, existing rooftop equipment, and building code requirements for every building. In addition, areas between buildings can be evaluated for installation of shading structures that support solar PV. These types of structures are commonly used to cover parking lots to provide shade for parked vehicles while also providing renewable electricity, commonly known as car shade structures. The goal of the survey is to use aerial images, such as what is shown in Figure 17 to predict the maximum solar PV hosting capacity.

As a first step, off-the-shelf solar PV analysis tools can be used to predict the maximum solar PV capacity. For this purpose, the team used the PV_Lib toolbox produced by Sandia National Laboratories [13]. Researchers can use this tool to predict the maximum and most efficient solar PV system. Although this type of analysis does not include existing rooftop equipment or building code requirements, this quick approximation can establish solar PV limits, allowing for other aspects of the AEC design to continue while refining the solar PV hosting capacity.

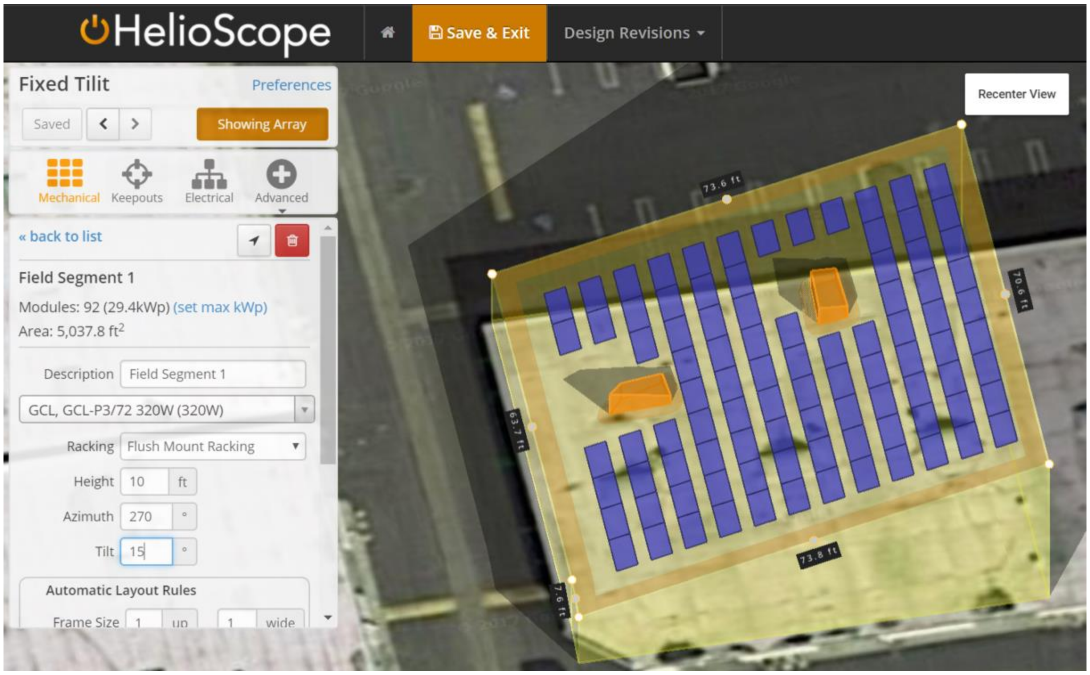
Figure 17: Aerial Image of Oak View Community



Source: Google Earth, modified by University of California, Irvine [12]

After the maximum solar PV capacity has been determined, the team used Helioscope [14] to predict the maximum solar PV hosting capacity for each building. Helioscope uses a graphical interface in which the user can take an aerial image of the building rooftop, orient and scale the available area, and select keep outs due to existing building mounted equipment. Helioscope also allows for the user to select how the power electronics are organized through the solar PV system. An example of the Helioscope graphical user interface is shown in Figure 18.

Figure 18: Example of Helioscope Graphical User Interface



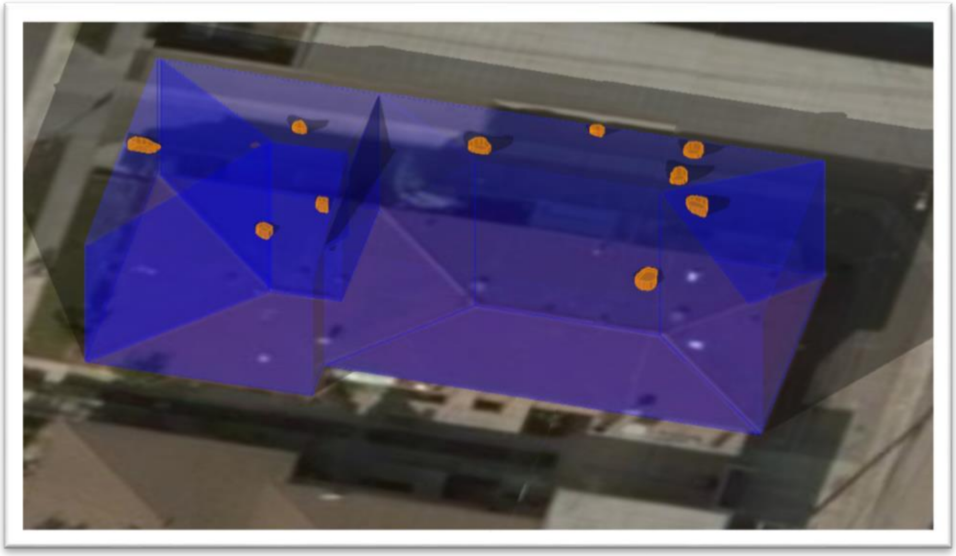
Examine rooftops for preexisting equipment. Figure 19 on the following page shows an example of this with the Helioscope software being used to locate areas on the roof with preexisting equipment, such as exhaust ducts, air conditioning units, or other systems. In addition to accounting for “keep-out” areas, appropriate setbacks from the edge of a roof or change in angle on the roof must be taken into account as set by local and state building codes. After keep-outs and setbacks have been considered, a model in which solar PV panels are placed on the rooftop can be generated.

Source: University of California, Irvine

Using the PV_Lib and Helioscope tools, the team established six steps to estimate the maximum solar PV potential:

1. Estimate rooftop and open car shade areas using aerial images. Using these estimates, establish the ceiling value for the maximum solar PV potential.
2. Examine system design and losses. As the solar PV panels are being placed, it is important to select the optimal wiring, orientation, and mounting style of the solar system to minimize energy losses. This will not only affect the panel output, but also how many panels can be placed on a rooftop as shown in Figure 20 below.
3. Consider different solar PV designs for each sector. Due to the possibly wide variety of building types in a community, it is important to understand how building end use can affect solar PV design. For example, within a residential sector, most of the rooftops are likely to be tilted, resulting in the possibility of rack mounting the solar PV panels parallel with the rooftop. In commercial and industrial sectors, where buildings may have flat roofs more often, a tilt design is likely necessary. In educational sectors, safety limitations and regulations will limit solar PV systems. Within each sector, there may be different focuses when designing the solar PV system, which must be taken into account. For example, Figure 21 on the next page shows three examples of solar PV design in the residential sector: Group A maximizes solar PV production, Group B, shifts panels to more efficiency locations only, and Group C includes setback requirements.

Figure 19: Drawing Out and Generating 3D Obstructions on Rooftop

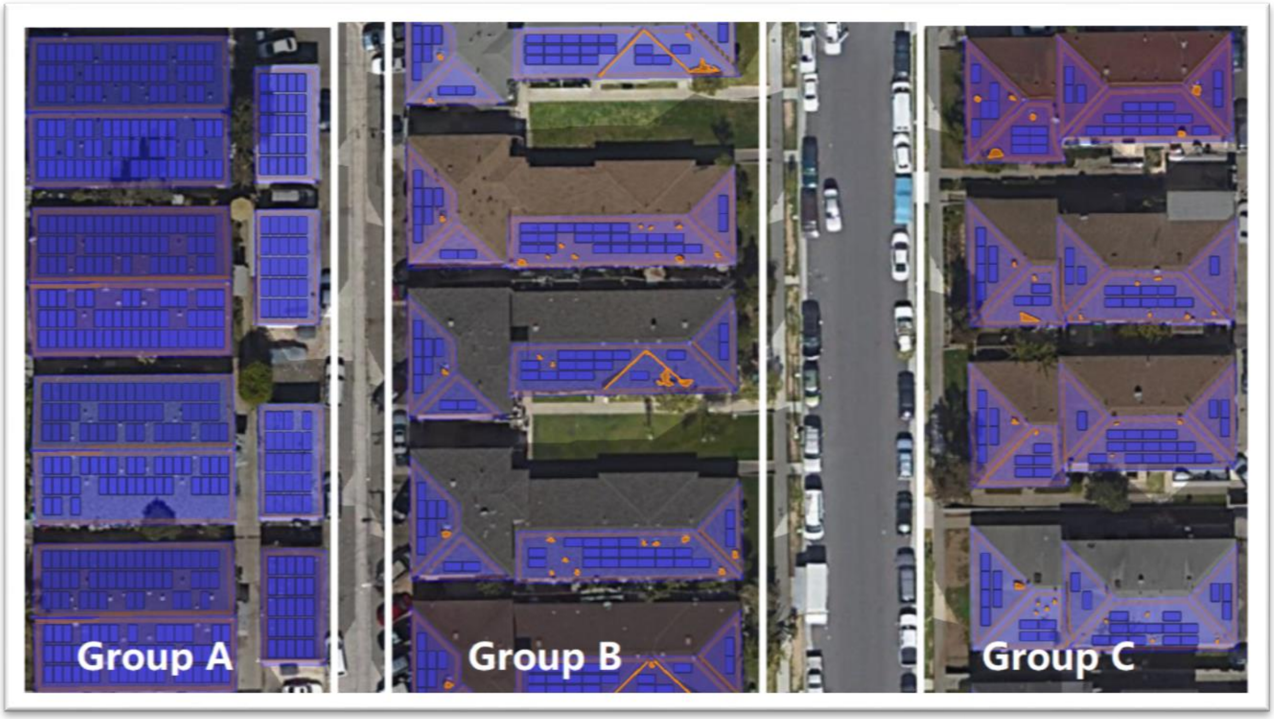


Source: University of California, Irvine

Figure 20: Rooftop with Solar Photovoltaic Array with Appropriate Setbacks

Source: University of California, Irvine

Figure 21: Community Solar Photovoltaic System Design Approach Considerations for Different Residential Rooftop Systems



Source: University of California, Irvine

4. Develop zone map based on electrical utility transformer locations. As realistic solar PV systems are being designed, it is important to understand how the systems will interact with the electrical utility whenever solar generation is greater than the building load. In this instance, the excess solar generation is typically exported back to the utility grid, with the first point of contact with the utility being through the local transformer. For a community solar PV system, multiple buildings could be connected to a single transformer, meaning that there could be instances when multiple solar PV systems are exporting electricity at the same time back to the grid through the same transformer. The transformer capacity, connected buildings, and potential export must be tracked to ensure that the total exported electricity does not exceed the transformer power ratings. The first step is determining which buildings belong to which transformers. An example within the Oak View community is shown in Figure 22, which shows the transformer map with buildings collected into groups.
5. Generate community solar PV designs. After the rooftop and car shade potential area for each building and location has been determined, then different scenarios can be developed for the community solar PV system. The most obvious of these scenarios is the maximum capacity scenario. This is necessary for other models to determine the maximum rooftop area that can be covered. However, other scenarios can be developed as different ownership structures are explored. For example, if the solar PV generation were to be purchased and installed by the local utility, it is likely that the utility would

primarily be interested in larger capacity systems due to economies of scale and difficulties with interconnecting the system with the larger grid. To address these issues, the maximum community solar PV survey can be used to filter the buildings down to a set of properties that can support a certain size system or larger. As a result, the maximum solar PV for this scenario can be determined.

Figure 22: Transformer Map for the Oak View Community

Source: University of California, Irvine

DERopt: Distributed Energy Resource Optimization

The process of selecting, sizing, locating, and dispatching DER is highly complex with many interdependent variables. Optimizing the performance of such a system can be difficult unless advanced techniques are applied that provide structure and clear solution paths to finding the actual optimal solution. An ideal tool for this task is mathematical optimization. Mathematical optimization requires the designer to generate a set of equations that link the cost of pursuing different actions with the real constraints that limit the designer's choice. In the case of the AEC, the goal is to minimize the cost of energy while always meeting the community energy demand. In this case, the AEC designer has the option of purchasing electricity from the grid, or purchasing DERs to generate and store useful energy onsite. Mathematical optimization is well suited for Oak View since there are more than 300 buildings, each of which can select multiple types of DER and operate the DER systems differently throughout the year. By generating an optimization problem, the AEC designers can consider every feasible scenario and find an optimal DER design.

The project team developed an optimization tool to allocate (size and site) DER in the AEC, namely, DERopt[15]. In this instance, the DER sizing and dispatch problem occurred for a single building, considered to be a single node. For this project, it was adapted to a multi-nodal approach to size DER for multiple buildings, where the entire system (loads and DER resources) are connected to spatially resolved nodes instead of a single physical node. The multi-nodal method allows modeling of the electric power distribution grid and the constraints involved with this physical network and equipment (wires and transformers). By using a multi-nodal approach, a community-scale solar and energy storage system can be designed such that commercial, industrial, and residential utility rates can be applied to individual buildings, utility restrictions can be applied, and solar/energy storage systems can be sized for each building such that community savings are maximized. This method is hypothetically superior to the traditional DER sizing method in which each building is considered individually because it considers total community energy use and limitations on how to reduce the overall load. This allows for targeted investment in the community to maximize the marginal benefit of every invested dollar, equitable access to the economic benefits of solar PV systems, and feasible interaction with the local electric grid. Note that this approach is scalable by building type and number and by technology type.

This model also captures electrical utility rates for all building and sector types and the intricacies of exporting electricity. Most notably, the program captures the difference between net energy metering (NEM) and wholesale rates. Under NEM rates, a utility customer can export electricity at the rate at which it is purchased, or retail rates, minus a nonbypassable charge (typically around $0.02 per kWh). However, under NEM rates, a utility customer can only export as much electricity as is imported, and the customer can only offset their own bill, not receive payment. If more electricity is exported than imported, the excess rates would not be credited to the utility customer under NEM rates. The utility customer could receive payment for their excess electricity which would be sold under wholesale rates, if they are a net electrical exporter. However, wholesale rats are much less valuable than retail.

As other types of clean and renewable generation become available, the model can be modified to include the impact of new and emerging technologies. Currently, the model only considers solar PV and EES for adoption. Within EES, the model considers if the storage is exclusively paired with a renewable generator, or if it can be charged using non-renewable resources. In this work, electrical energy procured from the utility is considered non-renewable.

The considered system architecture is presented in Figure 23 and shows a building electrically connected to the utility grid through transformer T1. All electrical service at the building, including import and export, must pass through transformer T1. At the building, three separate DER technologies can be adopted; solar PV, REES, and EES. Solar PV is the only type of onsite generation that can be adopted. If adopted, renewable energy produced from the solar PV can be either a) sent directly to the building, b) exported back to the grid under net energy metering (NEM) rates, c) exported back to the grid under wholesale rates, d) stored in an energy storage system exclusively supplied by onsite solar PV, e) stored in an energy storage system that can also store imported utility electricity, or f) curtailed. There is a distinction between energy storage powered only by onsite solar PV (or REES) and energy storage that can also be charged using grid electricity (or EES), because only energy storage exclusively charged using renewable energy is allowed to export electricity back to the grid under net energy metering rates.

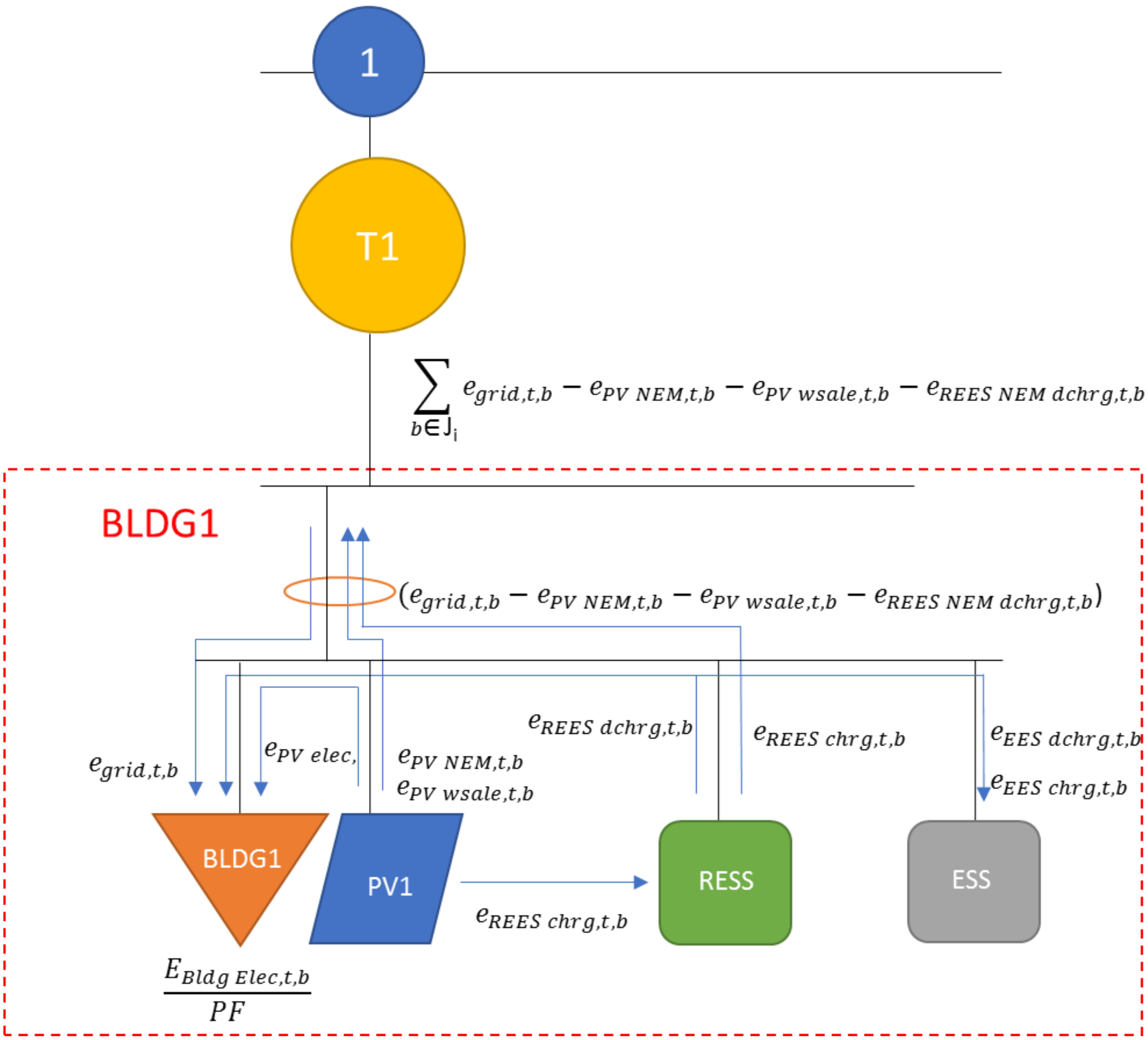
These decisions are depicted in Figure 23, with the REES receiving energy only from the solar PV system while being able to also send electricity back to the utility, and the EES receiving energy from both onsite solar PV and utility import, but only being able to discharge energy to meet building demand. Figure 23 shows a building system outlined in a red dashed square tied to transformer T1. In general, multiple building systems would be connected to the electrical system through a single transformer. For the Oak View community, the 314 modeled buildings are connected to the electrical distribution system through 47 transformers. When multiple buildings are connected to a single transformer, the flow of energy through the transformer is considered to be the sum of all energy flows to and from each building. This is indicated through the use of the summation symbol directly below T1 indicating the sum of all energy flows to and from the local utility.

DERopt is capable of optimally selecting and dispatching DER across an AEC community. The full detailed DERopt model can be found in Appendix A. The input to the DERopt model is the URBANopt energy profile outputs for each individual building in the AEC design area.

DER Operational Feasibility

To ensure that the selected DER system is capable of operating within the Oak View electrical infrastructure, additional modeling must occur to capture the effects, and any possible problems, caused by extensive DER integration and operation. This model needs to capture the properties of the current electrical infrastructure, and also needs to include the effects on the infrastructure caused by new onsite generation and storage. The most accurate method for determining these effects is to generate a power flow model that captures the physics of these complex systems.

Figure 23: Schematics of Multi-nodal Modeling Approach



Transformer T1 is one node, to which a cluster of buildings and DER are connected

Source: University of California, Irvine

To develop this model, the transformer map developed during the solar PV capacity survey must be used to determine which buildings are linked to what transformer, and to also determine what the transformer electrical throughput capacity is. In addition to transformers, the wires connecting the transformer to the larger utility circuits must be used. Two separate tools exist for establishing these utility connections. First, the local utility, Southern California Edison has generated an ArcGIS file that contains the locations and connections created by all major electrical circuits [16]. This resource allows the AEC designer to determine the major transmission and distribution circuits that serve the AEC community. These files do not show the wires that branch into each community to serve the individual buildings. To track these wires that link the local transformers to the larger utility circuits, aerial images can be used to determine wire locations. Any other wire locations that cannot be determined using aerial images require a site visit to determine location, orientation, and points of connection. Once this information has been collected and the results from URBANopt and DERopt are available, the power flow simulation can be executed. For this work, the power flow simulation tool ETAP was used [10].

Renewable Fuel Production

The majority of technologies considered in this work directly impact electricity use throughout the community. Although electricity use is a major aspect of the project, the use of fuels in the community cannot be ignored. This requires additional research into and understanding of local production of renewable fuels.

There are multiple pathways through which renewable fuels can be created. Two primary pathways are converting biodegradable material into carbon-based fuels and using renewable energy to electrolyze water into hydrogen gas. Secondary processes can be applied to further refine these fuels or convert them to a different end product.

Biodegradable material, usually organic matter, is defined as material that can be used as nutrients by microorganisms. Microorganisms can digest biodegradable material aerobically, with oxygen present, or anaerobically, without oxygen. The two main gaseous byproducts of anaerobic digestion of organic material are methane (CH_4) and carbon dioxide (CO_2). Methane is the main component of natural gas, a commonly used fuel, and the methane produced by anaerobic digestion can be extracted and used as fuel or injected into a natural gas pipeline.

Steam or water electrolysis involves passing an electric current through ionized water to chemically decompose water into oxygen and hydrogen. The net electrolysis reaction can be written as:

$$H_2O \rightarrow H_2 + \frac{1}{2}O_2.$$

in Chapter 1 shows a reversible fuel cell as part of the project team's AEC vision. The particular type of type of fuel cell considered in this work is the reversible high temperature solid oxide fuel cell (SOFC). When operating as a fuel cell, fuel and are sent to the SOFC, producing electricity. This type of technology can be operated in reverse as a solid oxide electrolyzer cell (SOEC) where electricity and water are put into the system, and hydrogen and oxygen gas are produced. As reversible SOFC/SOEC systems are not yet commercially available, the researchers used the 72 percent efficient alkaline electrolysis process for all further analyses [17] . Note that natural gas primarily consists of methane, not hydrogen. Although the current natural gas system can tolerate hydrogen injection, high concentrations of hydrogen in the current natural gas distribution system is not allowed. As a result, there is some interest in pursuing the conversion of hydrogen into methane through the methanation process. Methanation is the process of synthesizing methane from hydrogen and carbon oxides, commonly carbon dioxide [18]. This balanced chemical reaction is written below.

$$4\ H_2 + CO_2 \rightarrow CH_4 + 2\ H_2O$$

CH_4 conversion from CO_2 is typically high 80-90 percent [19]. The research team assumed an 85 percent CH_4 conversion.

Considering the multiple ways in which renewable fuels can be generated, six end-use paths were considered for the gaseous fuels in this work. A summary of the technologies used in each path is shown in Table 1.

Table 1: Technologies Included in End Use Paths Considered

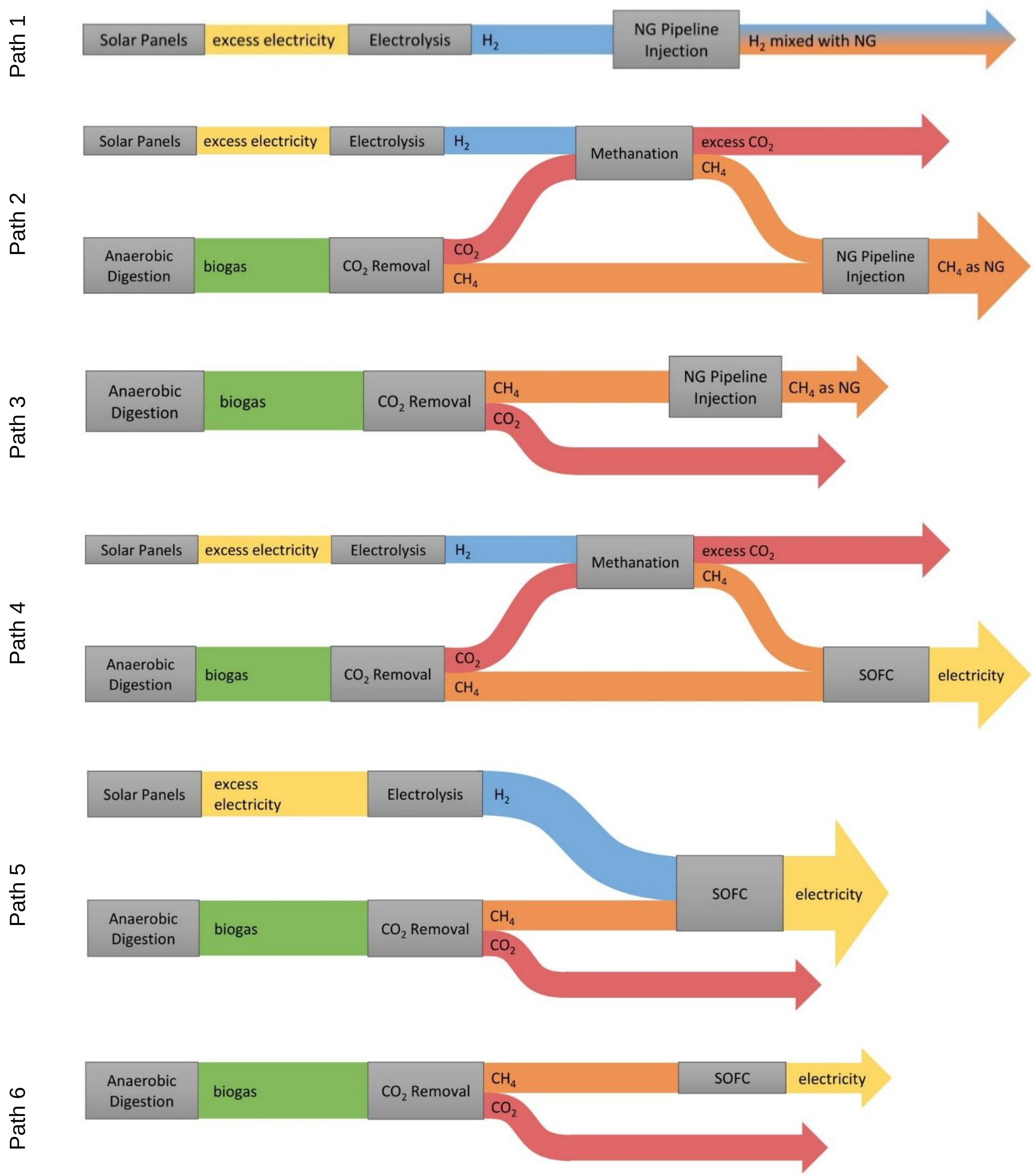
	Included Technologies					Path Description
	Anaerobic Digestion (AD)	Electrolysis (EC)	Methanation (MT)	SOFC	NG Pipeline Injection	
Path 1	X	✓	X	X	✓	Natural gas pipeline injection of hydrogen fuel from EC
Path 2	✓	✓	✓	X	✓	Natural gas pipeline injection of methane fuel from AD, EC, and MT
Path 3	✓	X	X	X	✓	Natural gas pipeline injection of methane fuel from AD
Path 4	✓	✓	✓	✓	X	Electricity production via SOFC using methane fuel from AD, EC, and MT
Path 5	✓	✓	X	✓	X	Electricity production via SOFC using methane fuel from AD and hydrogen fuel from EC
Path 6	✓	X	X	✓	X	Electricity production via SOFC using methane fuel from AD

Source: University of California, Irvine

Figure 24 provides energy flow pathways from input energy to output fuel product. All paths yield one of two main products: electricity production via solid oxide fuel cell (SOFC) or methane injection into the existing natural gas pipeline infrastructure.

Paths 1-3 end with generated fuel being injected into the natural gas pipeline. Paths 4-6 end with electricity generation from produced fuel via SOFC with 60 percent electrical efficiency. All renewable fuel production calculations consider only the food and yard waste for residents of the AEC design area. Although the current work will consider a location with a waste transfer station that services a larger portion of Orange County, the Oak View contribution to the waste traveling through this facility will be scaled down based on per capita trash production values provided by the City of Huntington Beach.

Figure 24: Energy and Material Flowcharts throughout Fuel Production and Consumption Process for End-use Cases



Width of lines are not drawn to scale and do not include inefficiencies and energy losses.
Source: University of California, Irvine

CHAPTER 5: Financing

Understanding the available funding options is critical to energy project design and development. Without feasible funding mechanisms and financial design, a community-scale project cannot be implemented. The following sections provide information on a number of potential energy funding methods. Opportunities covered include:

- Public-private partnerships
- Common energy project financial models
    - Energy savings performance contracts (ESPCs)
    - Power purchase agreements (PPAs)
    - Shared savings contracts
    - Operating and capital leases
- Energy-efficiency loan programs
    - Residential loans (home energy upgrade financing and residential energy efficiency loans [REEL])
    - Property Assessed Clean Energy (PACE) Program
    - On-bill financing
- Grant programs (Low-Income Weatherization Program [LIWP], Low-Income Home Energy Assistance Program [LIHEAP] and Community Development Block Grants Program [CDBG])
- Rebate and incentive programs
    - Utility rebates and incentives
    - Solar on Multifamily Affordable Housing (SOMAH) Program
    - Single-Family Affordable Solar Homes (SASH) Program
    - Net metering, virtual net metering and demand response
    - Energy Savings Assistance Program (ESA)
    - Energy Upgrade California Home Upgrade Program
- Community-scale energy funding methods
    - Community solar
    - Community Choice Aggregation (CCA)
    - Rotating energy fund
    - Preferred Resources Pilot (PRP)
    - District energy systems (DES)

This list includes local, state and federal sources and programs for EE financing. Although the project team researched all programs, a smaller subset was evaluated for the Huntington Beach AEC project. These sets of funding mechanisms support AEC implementation. The challenge for an AEC developer is to determine the optimal group of funding mechanisms to help realize the AEC. This section describes different funding mechanisms, programs, and strategies that can be used to garner support for an AEC project.

Public-Private Partnerships

A Public-private partnership (P3) is likely the best fit for funding the Huntington Beach Advanced Energy Community (HB AEC) and other similar AEC projects. According to the National Council for Public-Private Partnerships (NCPPP), a P3 is defined as "a contractual arrangement between a public agency (federal, state or local) and a private sector entity. Through this agreement, the skills and assets of each sector (public and private) are shared in delivering a service or facility for the use of the general public. In addition to the sharing of resources, each party shares in the risks and rewards potential in the delivery of the service and/or facility."

An International Energy Agency (IEA) report entitled "Joint Public-Private Approaches for Energy Efficiency Finance" identifies three common P3 mechanisms for financing EE projects:

- Dedicated credit lines: credit lines established by a public entity (such as a government agency and/or donor organization) to enable financing of EE projects by a private-sector organization (bank or financial institution).
- Risk-sharing facilities: partial risk or partial credit guarantee programs established by a public entity (such as a government agency and/or donor organization) to reduce the risk of EE project financing to the private sector (by sharing the risk through a guarantee mechanism), thereby enabling increased private sector lending to EE projects.
- ESPCs: public-sector initiatives, in the form of legislation or regulation, established by one or more government agencies to facilitate the implementation by energy service companies (ESCOs) of performance-based contracts using private-sector financing.

For example, a P3 for the Huntington Beach AEC project can be viewed as a partnership between the California Energy Commission and private equipment manufacturers, installers and operators. The NCPPP describes the following seven steps as best practices for delivering a successful P3:

1. Public sector champion: Recognized public figures should serve as the spokespersons and advocates for the project and the use of a P3. Well-informed champions can play a critical role in minimizing misperceptions about the value to the public of an effectively developed P3.

2. Statutory environment: There should be a statutory foundation for the implementation of each partnership. Transparency and a competitive proposal process should be

delineated in this statute. However, unsolicited proposals can be a positive catalyst for initiating creative, innovative approaches to addressing specific public-sector needs.

3. Public sector's organized structure: The public sector should have a dedicated team for P3 projects or programs. This unit should be involved from conceptualization to negotiation, through final monitoring of the execution of the partnership. This unit should develop Requests for Proposals (RFPs) that include performance goals, not design specifications. Consideration of proposals should be based on best value, not lowest prices. Thorough, inclusive value for money (VFM) calculations provide a powerful tool for evaluating overall economic value.

4. Detailed contract (business plan): A P3 is a contractual relationship between the public and private sectors for the execution of a project or service. This contract should include a detailed description of the responsibilities, risks and benefits of both the public and private partners. Such an agreement will increase the probability of success of the partnership. Realizing that all contingencies cannot be foreseen, a good contract will include a clearly defined method of dispute resolution.

5. Clearly defined revenue stream: While the private partner may provide a portion or all of the funding for capital improvements, there must be an identifiable revenue stream sufficient to retire this investment and provide an acceptable rate of return over the term of the partnership. The income stream can be generated by a variety and combination of sources (fees, tolls, availability payments, shadow tolls, tax increment financing, commercial use of underutilized assets or a wide range of additional options), but must be reasonably assured for the length of the partnership's investment period.

6. Stakeholder support: More people will be affected by a partnership than just the public officials and the private sector partner. Affected employees, the portions of the public receiving the service, the press, appropriate labor unions and relevant interest groups will all have opinions and may have misconceptions about a partnership and its value to all the public. It is important to communicate openly and candidly with these stakeholders to minimize potential resistance to establishing a partnership.

7. Pick your partner carefully: The "best value" (not always lowest price) in a partnership is critical in maintaining the long-term relationship that is central to a successful partnership. A candidate's experience in the specific area of partnerships being considered is an important factor in identifying the right partner. Equally, the financial capacity of the private partner should be considered in the final selection process.

Common Energy Project Financing Models

Many procurement models are commonly used for financing energy projects. Many are loan structures that provide access to additional capital for project owners. These loans may also shift ownership, operation and maintenance of equipment to a third party to reduce performance risk for owners. In some cases, a performance guarantee is used to ensure that the predicted benefits are realized. Often these structures allow a private entity to capture federal tax incentives for the energy project. This can reduce project costs to public entities, or private entities without the tax designation, who partner with the private entity.

Energy Savings Performance Contracts

In this model, the property owner finances an energy project with an ESCO. The ESCO acts as a general contractor to install the energy conservation measures and the property owner owns and operates the equipment. A performance contract is used to guarantee a certain level of energy savings over a set period of time. The savings are the basis of positive cash flows used to pay off the project loan. Typically, baseline energy use is established prior to project implementation and post-implementation savings are measured against the baseline. Benefits of the ESCO model include access to capital, a structure that may be cash flow neutral (or positive) and potentially lower risk compared to direct ownership. The downside of an ESPC is high overhead to cover ESCO risk.

Power Purchase Agreement

Under a power purchase agreement, a third party owns, operates, and maintains a solar PV system and sells the electricity back to the property owner under a negotiated rate and escalator. This allows the property owner to use renewable energy with no upfront capital investment. The property owner benefits through utility cost savings and the PPA provider receives relevant tax incentives. For solar PV, the term of a PPA normally ranges between 20 and 25 years. The PPA provider can either be a commercial solar provider or a utility.

Shared Savings Contract

This example of a shared savings contract is focused on a solar PV system installation, but could be extended to include energy conservation measures. With a shared savings contract, a solar PV system is owned, operated and maintained by a third party and the electricity is sold directly to the property owner. The energy cost savings from the solar system is divided between the property owner and the third party.

Operating Lease (“True” or “Tax” Lease)

This example of an operating lease is focused on a solar PV system installation, but could be extended to include energy conservation measures. An operating lease is a common solar lease structure where the property owner pays the lessor of the solar system a monthly installment regardless of the energy generated by the solar PV system. The property owner operates and maintains the system and receives all energy savings during the lease period. The lessor receives all tax benefits, including depreciation. Lease payments can be deducted as an operating expense, which can lower taxes compared to a capital lease. Lease terms are usually 7 to 15 years. At the end of the term the property owner can return the system, purchase the system for “fair market value,” or renew the lease. For “true” leases, transfer of ownership prior to the maturity of the lease is not allowed.

Capital Lease

This example of a capital lease is focused on a solar PV system installation, but could be extended to include energy conservation measures. A capital lease is similar to an operating lease. In a capital lease, the property owner (lessee) purchases the solar PV system at the end of the lease term for a negligible amount (usually $1). All tax benefits and electricity savings are given to the lessee. Capital leases usually have higher monthly payments than operating leases and the terms of the lease are generally between 5 and 10 years. Capital leases are only available to for-profit entities.

Energy-Efficiency Loan Programs

Loan-based financing can provide the capital necessary to implement an energy project. In many cases, an energy project has the potential to deliver attractive cost savings, but the property owner or project implementer lacks sufficient capital to pursue the project. A property owner may simply tap a line of credit to supplement available capital. However, there are many resources available from utilities, governments and the private sector for energy projects that provide advantages over traditional loans. Some offer low or zero interest loans, waived fees, longer repayment periods, less stringent credit requirements, or use of non-traditional forms of collateral. Many programs are designed for low-income properties. Loans can help expand the available resources to achieve more impactful projects.

Home Energy Upgrade Financing

SoCal Gas offers loans to all homeowners to upgrade equipment including water heaters, space heaters, cooling equipment, wall, ceiling and attic insulation and cool roof technologies. Financing ranges from $2,500 to $30,000 depending on the equipment upgrade. Loan terms are from three to ten years with twelve-year repayment available for ENERGY STAR® certified equipment.

Residential Energy Efficiency Loans

California provides financial support for energy efficient upgrades in the form of EE loans which offer improved rates and terms compared to other loans. REELs are offered by multiple lenders, is restricted to properties with one to four units and must be executed by the property owners. At least 70 percent of the loan must go towards EE measures, such as upgrades involving HVAC, water heaters, insulation and air sealing, LEDs, appliances, smart thermostats, etc. There are no income restrictions on applications for REEL funding.

Affordable Multifamily Financing Pilot Program

The California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA) is piloting a financing program for multifamily properties where at least 50 percent of the units consist of income eligible households. Similar to REEL financing, this program offers loans focused on upgrades for HVAC, water heater, insulation, LED, and so on. This program offers the added benefit of on-bill repayments for master-metered properties. Currently, the program is in the initial phase and is conducting shareholder and public workshops.

Property Assessed Clean Energy Program

Through state or local government PACE funding, a property owner can finance EE-related upgrades to their home or business with no initial investment of capital. Through the two PACE programs, HERO financing and CaliforniaFIRST efficiency financing, property owners can upgrade HVAC, insulation, weatherization, windows, solar panels, etc. In addition to EE measures, PACE financing also covers upgrades for reducing water use. Loans accumulated through projects can be paid off through assessments on the property tax bill and loan terms can extend up to a maximum of 30 years.

On-Bill Financing

Non-residential utility customers are offered on-bill financing, with no interest or fees that can be repaid in installments recorded on the utility bill. This financing option is offered in conjunction with express, customized, or third-party EE projects eligible under the program. Loan size is based on service account energy use, number of facilities on the account and whether the loan is on an individual or bundled/consolidated basis. The loan minimum is $5,000. For government and institutional customers, the loan cap is $250,000 with a repayment lifetime of up to 10 years. For business customers, the loan cap is $100,000 with a repayment lifetime of up to 3 years for lighting projects and up to 5 years for non-lighting projects. As an added restriction, on-bill financing does not apply to projects where single end use lighting measures comprise more than 20 percent of the total project costs.

Grant Programs

Grants are non-repayable funds or products disbursed or gifted by one party (grant makers), often a government department, corporation, foundation or trust, to a recipient, often (but not always) a nonprofit entity, educational institution, business or an individual. Grant funding can supplement capital for eligible projects. The advantage of grants over loans is that there is no obligation for repayment. There are multiple grants available for low income energy projects.

South Coast Air Quality Management District Project Funding

The South Coast Air Quality Management District (SCAQMD) funds projects that qualify under the Air Pollution Control Projects That Reduce/Mitigate Emissions/Toxic Exposure program. The projects are financed through SCAQMD special revenue funds. Projects with environmental justice elements or that are enacted within a disadvantaged community will receive additional consideration. Total funding available for a variety of SCAQMD project categories range from $100,000 to $18 million. Projects that qualify can include renewable power generation at public buildings, residential solar installation with corresponding electric appliances, weatherization upgrades, electric charging stations and energy storage technologies.

School Facilities Modernization Grants

This grant is focused on renovating school facilities more than 25 years old and can be used towards upgrading air conditioning systems, insulation, roof replacement and new furniture and equipment. The amount is awarded based on the number of students attending the school, but the district may be eligible for additional funding based on the project scope. The grant is offered by the state of California's Department of General Services, Office of Public School Construction.

Low-Income Weatherization Program

The State of California offers free services which can include installing solar panels, solar hot water heaters and EE measures in low-income single family and multifamily dwellings. The LIWP utilizes funding from a variety of state and federal sources to provide upgrades. The grant is provided by the California Department of Community Services and Development.

Low-Income Home Energy Assistance Program (LIHEAP)

Through the LIHEAP, low income homeowners and renters are given federally funded assistance 1) with home energy bills, 2) in cases of energy crises and 3) towards weatherization and energy-related minor home repairs. LIHEAP is administered by the United States Department of Health and Human Services and paid for through block-grant allocations. This program is targeted at low-income residents who are eligible for other assistance programs.

Community Development Block Grants Program

The CDBG program aims to help low-income communities by funding affordable housing, providing general services and job creation. In the HB AEC application, the CDBG could be a source for funding solar installations and building envelop improvements for low-income housing within the community. CDBG program is funded through HUD and amounts are awarded based on a variety of factors the establish community need. Other state programs (such as LIHEAP and LIWP) have access to these block grants and it is likely CDBG funding could be established through those channels.

Rebate and Incentive Programs

There are general rebate and incentives programs available at the utility and government levels, including programs specifically designed for low income communities or applicable to AEC design. These programs can help reduce project costs for various stakeholders engaged in an AEC project.

For projects focused on bringing EE to a low-income community, programs such as ESA, MIDI, SOMAH and SASH can be used to leverage the existing funding the AEC project provides. Other programs such as virtual net energy metering can be leveraged to equitably spread the benefits of applying solar within the community. Partnering with the utilities to enact DR programs within the community further enhance the 'advanced' aspects of the design. With the utilities as key shareholders in the project development, the potential for these programs will be further assessed in the context of the community design.

Solar on Multifamily Affordable Housing (SOMAH) Program

SOMAH is a California state program that provides financial incentives for solar PV systems installed on multifamily affordable housing properties. The SOMAH program allocates $100 million annually for ten years towards solar incentives and intends to develop 300 megawatts

(MW) of solar capacity by 2030 and reduce the CARE subsidy through positive investments in renewable energy generation.

Single-Family Affordable Solar Homes Program

The California state-funded SASH program is designed to give single-family homeowners in low-income community's access to solar PV systems through up-front rebates. The program also allocates funding to provide education on the benefits of EE and solar technologies, as well as supports local green-job training and workforce development. While the program was originally scheduled to sunset in 2015, funding for the program has been renewed through 2021. The program is managed by GRID Alternatives, a non-profit solar contractor, which uses a third-party ownership model to best leverage project funding.

Southern California Edison Rebates and Incentives

SCE offers rebates for residential, multifamily, commercial and industrial utility customers installing energy efficient equipment. Rebate amounts vary by category, energy reduction and customer type. Residential rebates include smart thermostats, evaporative coolers and hybrid electric heat pump water heaters. Multifamily rebates include LED T8 replacements, evaporative cooling technology and high efficiency clothes washers. Multifamily (common areas only), commercial and industrial rebates can include lighting, HVAC, office equipment and refrigeration and process equipment with both customized and express solutions packages available. On-bill financing is available to non-residential customers for EE projects. Additionally, SCE offers incentives for retro-commissioning services that can be provided to business customers.

Additional Southern California Edison Programs: Net Energy Metering and Demand Response

The Net Energy Metering (NEM) program offered by SCE is applicable to customers who produce their own electricity through a renewable energy generation technology. Customers receive a bill that shows their net energy consumption (total use less customer system generation). Any excess energy generated can earn surplus utility credit. NEM credits are valued at the retail electrical rate less a nonbypassable charge (typically $0.015 to $0.02 per kWh).

Virtual Net Energy Metering (VNEM) is a SCE program applicable to property owners with multiple service accounts. Typically, VNEM allows a solar PV operator to allocate NEM credits across multiple accounts located at the point of generation. A common application of this rate is for solar PV systems installed at a multitenant building where each tenant is individually metered. NEM credits can be shared across meters located at different buildings, provided that the buildings are located on the same parcel of land. To engage in the VNEM program, there are one-time setup fees to establish connection and fees associated with disconnection/reconnection.

DR programs aim to reduce energy use during times of peak grid use. Customers reduce costs by reducing load during a "demand event." The specific timing of the event is communicated to the service account holder by the utility. There are a variety of available DR programs that apply to specific equipment or customers.

Southern California Gas Company Rebates and Incentives

SoCal Gas offers rebates for a variety of energy efficient products that reduce natural gas use. Rebates are offered for products including smart thermostats, water heater rebates (both tankless and storage), clothes washers, low-flow fixtures, furnaces, clothes dryers and wall and attic insulation. Rebates are focused on ENERGY STAR® certified products and range based on upgrade cost. Additionally, SoCal Gas has worked with retailers to build the rebate into the product cost, i.e. purchasing a natural gas water heater at participating retailers will have the rebate already applied. SoCal Gas also offers free energy-efficiency starter kits which include low-flow water fixtures.

Energy Savings Assistance Program

The ESA Program is a SCE program aimed at replacing and upgrading energy intensive equipment for residential customers at low or no cost to the customer. The program is available to renters and property owners who are eligible for public assistance programs such as Medi-Cal/Medicaid, CalFresh/SNAP, LIHEAP, SSI and others. The program can be applied towards cooling equipment, refrigerator replacements, smart power strips, weatherization services, water heater repairs and lighting replacements. Participant eligibility is assessed by SCE.

Middle Income Direct Install Program

The MIDI program is designed for customers who just exceed the requirements described in the ESA program. The program functions similarly to the ESA program by offering low-or-no cost home improvement services to renters and home owners in single-family and multifamily housing. Products offered through the MIDI program include attic insulation, duct sealing, low-flow fixtures and thermostatic shower valves.

Energy Upgrade California Home Upgrade Program

This California state program reviews the potential EE savings for a home and offers rebates accordingly. Houses built before 2002 are eligible for program involvement. Program rebates are between $550 and $5,500 and can be applied to projects such as building and duct sealing, insulation, HVAC equipment, water heaters and energy-efficient windows. Basic Home Upgrade plans aim to reduce energy use by 10 percent while Advanced Home Upgrade plans target reductions of 45 percent. According to past program findings, an average $2,300 rebate covers approximately 15 percent of project costs.

Community-Scale Energy Financing Models

Community-scale energy funding models were reviewed as part of the final model development process. These models offer promising strategies for financing EE and distributed energy projects at the community-scale. However, these models do have their barriers. For example, EE project costs and benefits are typically tied to individual property owners, electricity cannot be "sold over the fence" between service account holders, and community-scale energy models may not pencil out financially. This increases the risk and the aversion of both investors and developers to employing these models. If leveraged correctly, however, community-scale financing models and strategies can benefit multiple partners in a community, allowing a successful AEC to be implemented.

Community Solar Projects

Community solar projects provide energy and financial benefits to multiple community members. Community solar projects are attractive because they allow access to solar for community members who do not the financial means (low-income residents) or the physical requirements (limited access to footprint, or a roof that is shaded or structurally limited, and so on). Community solar projects can improve economies of scale and provide optimal project siting. The community may also realize benefits related to opportunities for job creation and increased access to renewables.

Models previously mentioned in this report can be leveraged to create a community solar program (PPAs, NEM, and VNEM). In all cases, the benefits of generating or sourcing renewable energy, energy savings and tax reductions should flow in various ways to the stakeholders to create a successful project. The difficulties in creating a successful community solar program, especially in low-income areas, include overcoming price premiums for renewable energy, capital costs, regulatory, tax and energy pricing restrictions.

There are three main models which fall under community solar: utility-owned projects, special purpose entity (SPE) projects and non-profit projects. Each of these projects is defined by the solar PV system owner. In utility-owned projects, utilities finance and host the installation to offer solar energy generation to their customers and meet their Renewable Portfolio Standards. In SPE-owned projects, the members combine their investment with grants and other incentives to fund the development of the project by a third party. The community investors receive a return on the investment and the project offsets their electricity usage. In projects owned by non-profits, funding is provided by donor, member contributions and grants with the non-profit retaining system ownership and providing the benefits to its users. In many cases, this is a philanthropic investment for the donors.

Prior to 2018 in California, the main community solar program available was the Enhanced Community Renewables (ECR) program. Under the ECR, consumers enter into agreements directly with third-party developers to purchase solar or other clean energy as a community. Developers can then sell any excess power back to the grid. Barriers exist for widespread program implementation, specifically in regards to the inflated and fluctuating energy rates.

Community Choice Aggregator Programs

CCAs are government entities formed by cities and counties to provide energy procurement options to members of the community. The CCA is responsible for purchasing the electricity to meet the needs of its customers. This can entail purchasing a greater percentage of electricity produced by renewables and setting energy rates to better meet the needs of the community. Additional benefits of a CCA are that energy costs can be structured in a way to draw in new local businesses and jobs and the revenue from the service can provide funds for local programs. The provision of electricity generation from the existing electric utility becomes limited with a CCA. While the utility is no longer responsible for providing the community's energy procurement needs under a CCA, the utility will still maintain and charge for the transmission and distribution infrastructure responsible for delivery of electricity. In forming a CCA, communities would need to pay a power charge indifference adjustment to the utility as part of removing these consumers off the utility's long-term energy contracts. To-date, there are several CCAs that have been and are being established around California. Initial results for customers appear to be positive.

Rotating Energy Funds

Rotating energy funds (also known as revolving loan funds) allow for continued investment in renewables and EE projects through savings generated from past-projects. After the initial project investment, future projects can be implemented with reduced capital investment by leveraging energy savings. This encourages expanded savings through continuous energy project advancement. Rotating energy funds have been used within universities, cites and other organizations with a high level of success. This strategy provides an interesting opportunity for community-scale energy improvements where energy savings can be leveraged into future energy projects. Given the limited regulatory framework and funding in this area, there are large barriers to executing a rotating fund in a multi-owner community environment, However, even with the hurdles, rotating energy funds still show promise given their success in other large-scale applications.

Preferred Resources Pilot

The Preferred Resources Pilot is an SCE program that began in 2013. It was designed to bring renewable energy, energy storage, EE, and demand response to the Orange County area as "preferred" energy resources to compensate for the loss of the San Onofre nuclear power plant. PRP is an example of a local pilot project aimed at addressing energy at the community level and can act as a model for future AECs. The pilot is expected to provide 260 MW of capacity in the most affected region. The capacity is being fulfilled with a combination of technologies including solar PV, battery and DR. As of 2017, 76 MW of capacity had been installed with 56 MW planned for 2018. Although the pilot is no longer accepting new generation projects, the program provides precedent for SCE and other utilities to engage with AEC projects and provides a framework for future AEC project engagement. Under the scope of such a pilot project, an AEC can engage in community-scale DER and EE efforts.

District Energy Systems

District-scale energy projects share resources between facilities within a community to leverage economies of scale and maximize energy use and efficiency. In district energy systems, a central source produces electricity, steam or hot or cold water to the facilities within the system. This allows greater efficiency given an increased equipment size and maximized resource use. Heating and cooling between buildings and between systems may be exchanged. For example, the warm water leftover from cooling a building can be provided to a different building to preheat incoming cold water intended for domestic how water use, reducing the total energy demand of the system. Other systems can also be utilized under the DES model. In some cases, waste systems are used as a source of heat for buildings within the system. DES show promise, however, there are many hurdles associated with construction costs of the project and risk around offtake agreements. Additionally, in regions with little or no heating or cooling loads, the necessary savings from the project may not be realized.

CHAPTER 6: Design Method

After the AEC design and operation tools have been developed, and the partnership and funding opportunities have been determined, the next step is to determine the methodology through which an AEC will be designed. Considering the vast number of energy conservation measures (ECM), distributed energy resources (DER), and smart grid technologies, determining the optimal mix of resources is extremely challenging. While the tools developed for this project are capable of capturing the complex interactions between the different energy loads, ECMs, and DER technologies, a systematic approach must be outlined to ensure that each selected technology is optimally sized to maximize benefits.

Considering this goal, it is critical at the onset of AEC design to clearly define the goal of the AEC design. While the general desire is to minimize cost or maximize profit while reducing emissions, approaching or achieving net zero energy (ZNE), or increasing resiliency and energy service reliability, these different goals are often in competition with each other. For example, cost is likely to increase as cleaner technologies are selected, resiliency and reliability are increased, and the closer to ZNE to AEC adopters care to move. As a result, it is necessary for the AEC designers to determine their optimal selection criteria in a way that can be quantitatively measures to establish sufficient judging criteria to differentiate potential AEC technology scenarios.

Once the judging criteria has been selected, the process of determining optimal technology selection can occur in a coherent and quantitative manner. In addition, by establishing the range of possible technology adoptions, additional criteria can be applied to add nuance to the decision making that may be difficult to apply tangible costs to. For example, by determining a trajectory of optimal technology adoption to achieve ZNE, the AEC developer can see how much it costs to move incrementally closer to ZNE, and consider if the value of the shift is worth the additional cost.

After establishing the judging criteria, the design process can proceed through the following steps:

1. Determine critical community partners
2. Determine community partner energy use
3. Reduce possible AEC technologies based on approximate impact
4. Evaluate lower cost ECM options
5. Evaluate higher cost DER and ECM options
6. Consider ECM and DER options to reduce technology mixes to optimally performing set

Please note that completion of this process requires modeling tools to predict the future energy use of any included buildings and energy loads, and to predict the impact of ECM and DER operation on the community. The tools used for these processes in the current Oak View project are the URBANopt tool developed for ECM analysis and the DERopt tool developed for DER system analysis. In general, other tools can be used as long as the tools quantify the differences between the current community and the future upgraded community, and can determine the cost difference based on this energy difference.

Determine Critical Community Partners

Step 1 is associated with determining the properties and buildings to consider in the AEC design. This step would typically start with establishing geographical boundaries that set the limits of the AEC. Within this boundary, there may be certain parties best suited to AEC development. These decisions typically depend on the motivation for AEC development and the possible sources of investment and funding. For example, for areas with demographics associated with low socioeconomic levels, non-profit housing, educational, and community service organizations are likely to be the top priority when considering funding for low income individuals. For areas with higher socioeconomic levels, the higher income levels may justify additional spending on green energy technologies and the focus may be on privately owned single family residences.

In addition, it is important to determine the relevant organizations operating within the community. This may affect lower socioeconomic regions the most since nonprofit aid organizations can be leveraged to provide support in creating access to AEC technologies. Two examples of this in Orange County are Community Action Partnership Orange County (CAPOC) for EE and weatherization measures, and GRID Alternatives for low income solar PV support. By determining what types of organizations are active in the area, feasible ECMs can be expanded to include what is offered locally through these aid organizations.

Energy End-Use Profile

After community participants have been determined, the next step is to predict what future energy use will look like. In general, the most indicative measure of future energy use is prior energy use data, which can be accessed through the AEC community member's utility account. Ideally, time-resolved energy use data is available. In general, as long as a building tenant or load operator does not plan large changes to the structure or load, prior data can be used accurately to predict future energy use behavior.

If this energy use data does not exist, or the number of AEC residents is sufficiently large to create difficulty with wide-scale energy use data collection, then other methods can be employed, such as the use of energy use intensity values. Even better would be the use of building energy simulations, which can predict the use of energy within a building. The challenges associated with this method surround behavioral patterns that can deviate from typically assumed behavior. In addition, if unique loads exist within the community, such as industrial processing loads, and are not commonly found in other communities, then building energy simulations provide inaccurate results. However, this can be offset through site walks and energy audits, which can be easier to secure and perform than capturing energy use data. By combining building energy simulation tools with onsite operational insight, accurate energy models can be developed. In addition, if the AEC designer has access, then onsite metering of select locations can add additional information useful for the tuning of models. This process, however, takes time since the load must consistently occur over a long enough period to establish patterns in use that can be applied to the building energy simulations.

Pruning of Available Energy Conservation Measures

While community energy usage is being determined, the design team must determine which ECMs to consider during the AEC design. This activity is important due to the wide array of ECMs currently available, and the efficacy of each type to reduce energy cost given the AEC location. One obvious factor in evaluating ECMs prior to AEC design is local climate. For example, the Oak View community lies just inland from the Pacific Ocean, resulting in a relatively mild climate. In addition, site visits revealed that the community has little to no cooling within the residential zone. As a result, ECMs associated with lowering cooling demand are unlikely to be effective. If the goal is to reduce electricity usage in the AEC community, then the climate consideration would reduce the efficacy of such ECMs as weatherization, cool roof modifications, double pane windows, glazing over windows, and other measures that improve home sealing and resistance to absorbing solar radiation and heat from ambient air. Considering the common usage of these measures across California, a lack of consideration for the climate could have resulted in these measures being included in the general case study, increasing the burden of computing projected energy reductions for ECMs that will have little to no energy or cost savings benefits.

Other factors may need to be considered. For example, depending on available financial support, certain ECMs may not be available. This is also true of DER systems. In these cases, where the AEC design is economically limited, the process of pruning technologies is critical to evaluating the most important technologies that are being considered.

Energy Conservation Measure Evaluation

After the community energy use and possibly useful ECMs have been determined, the design team can make some technology selections purely based on typical cost and both energy and financial savings. This procedure would be considered selecting the most cost effective measures to include in the design before evaluating more expensive items. Examples of these cost effective measures are LED lighting, which has been shown in this work to have a simple payback of around one year. Considering the excellent financial performance of this technology, adoption of this measure would be recommended regardless of AEC implementation.

While LED lighting presents an obvious case for immediate adoption, other items may have poorer financial performance. For these ECMs, the system designer and evaluator should select certain performance criteria, such as simple payback, to establish a threshold for which a measure must meet to achieve immediate adoption. In the particular case of the Oak View community, energy efficient appliances do not perform as well as LED lighting. However, if the cutoff for technologies is set to ten years, then the evaluation of energy efficient appliances results in an immediate adoption due to payback occurring faster than ten years. Other criteria could include energy savings per dollar spent, or emissions reductions per dollar spent.

Analysis of the ECMs should take place using the methods used to predict building energy performance. In the particular case of the Oak View AEC, the selected tool was URBANopt, which was developed specifically for the Oak View AEC design. Also note that evaluation of easy to implement demand response measures should also be examined during this portion of AEC design.

Distributed Energy Resource and Energy Conservation Measure Evaluation

After the ECM evaluation has been evaluated, the next step is to examine the optimal mix of DER and other resources to help the AEC design achieve the predefined goals. Note that there are resources included in this section that can contain more expensive ECM items that did not achieve the automatic adoption threshold. Under this circumstance, there may be the potential for the ECM in question to not achieve the performance threshold, but outperform higher price technologies, such as solar generation paired with EES.

The fundamental requirement during this step is to use an evaluation method that evaluates all possible combinations of DER, expensive ECM, and more aggressive demand response programs. Note that a large number of any of these technologies paired with a large number of properties can quickly lead to an intractable problem. This challenge can be approached in numerous ways. First, the potential value to a generic property or building should be determined for each option to approximate the relative values of each measure or technology. Such a step can eliminate less effective measures and technologies. Second, similar options should be combined together when comparing the measure or technologies to other options. The basic assumption in this step is that relatively small differences in adoption impacts are generating when selecting between similar technologies when compared to the impacts of dissimilar technologies. As a result, the problem can be simplified without losing significant clarity of the optimal solution by combining similar technologies. An example of this would be multiple solar PV panel options with similar operating and cost characteristics. The third step is to reduce the length of time required to model the problem. Since building energy use tends to follow certain profiles, a representative load can be generated using multiple days' worth of data. This step reduces the length of time over which the analysis is being performed, reducing complexity. It is important to realize that this step can influence results negatively if the impact on certain technologies are not considered. For example, shortening the time over which a DER system is being analyzed can increase the impact of initial state of charge for any adopted EES, exaggerating the impact of the initial state on overall results. Finally, the AEC designer and implementer should adopt a systematic approach for evaluating the different DER options. The process must occur consistently to ensure that the results from different scenarios are comparable. This method could take the form of a formal optimization problem, as is used by the team designing the Oak View Advanced Energy Community. In this instance, the DERopt tool was developed to optimally size, site, and dispatch both solar PV and EES across the Oak View community.

Practical Advanced Energy Community Design

After all steps have been completed, the AEC designed will need post-design analysis to ensure the resulting AEC is technically feasible. This process should cover the basic technical details needed to ensure correct installation and operation of the proposed AEC. For example, the design must consider rooftop area constraints when determining the feasibility of any solar PV system. If this aspect is not taken into account earlier in the design process, such as through the implementation of a hard constraint during DER optimization, then this aspect must be considered during the post processing of the optimization results.

Another aspect that is likely to be important if substantial generation is to be adopted across the community is the impact on the local utility electrical grid. The proposed design must be capable of operating feasibly within the constraints of the local utility grid if the system is to be connected with the local utility. This analysis can be accomplished by developing a power flow model of the AEC community, and including the potential AEC DER design when considering the power flow through the different components of the grid.

Depending on the specific circumstances of an AEC, the requirements for feasibility may change. For example, local community constraints may require for additional considerations to be made regarding water usage. The considered impacts required to establish feasibility must be made according to the specific community. Assuming that the proposed design is feasible, then the AEC finance and business model must be considered to establish financial feasibility.

Financial Model Impacts

Note that the first step in this process requires determination of the project partners. This step is critical because these project partners will provide access to different types of technologies and funding streams. As different partner groups become available or existing partners leave the project, the AEC design process must be repeated if a significant difference in overall performance is expected. This must be understood during the design process to make sure any changes to the partner structure are reflected in the technical design.

CHAPTER 7: Modeling the Oak View Community

As the design team applies the process described in Chapter 0 to the Oak View community, information is required as input to many of the models. Most notable is information on the end use of each building included in this study and information on the local electrical infrastructure to determine DER design feasibility.

Oak View Building Classification

The total project area covers about one square mile and the estimated total building footprint is 1.8 million square feet. As seen in Figure 3 in Chapter 1, the community consists primarily of multi-family residential buildings, school/small commercial community buildings and industrial and larger commercial buildings (the business park). The number of structures, total floor area and a description is provided in Table 2.

Table 2: Oak View Building Count and Building Portfolio Description

Building Type	Number of Buildings (#)	Total Floor Area of Buildings (sq. ft.)	Building Portfolio Description
Residential	282	1,058,615	Residential sector consists mostly of multi-family housing with an average of four or five units per property. Shared common areas include clothes washers, dryers and hot water heaters.
Commercial	11	92,876	Commercial buildings include the elementary and preschool, the community library and community center. Other properties are small commercial buildings within the business park.
Industrial	18	641,653	Industrial buildings consist of a materials and waste processing facilities, warehouses, an auto shop and manufacturing related buildings.
Total	311	1,793,143	Community building stock is mixed, primarily consisting of residential buildings.

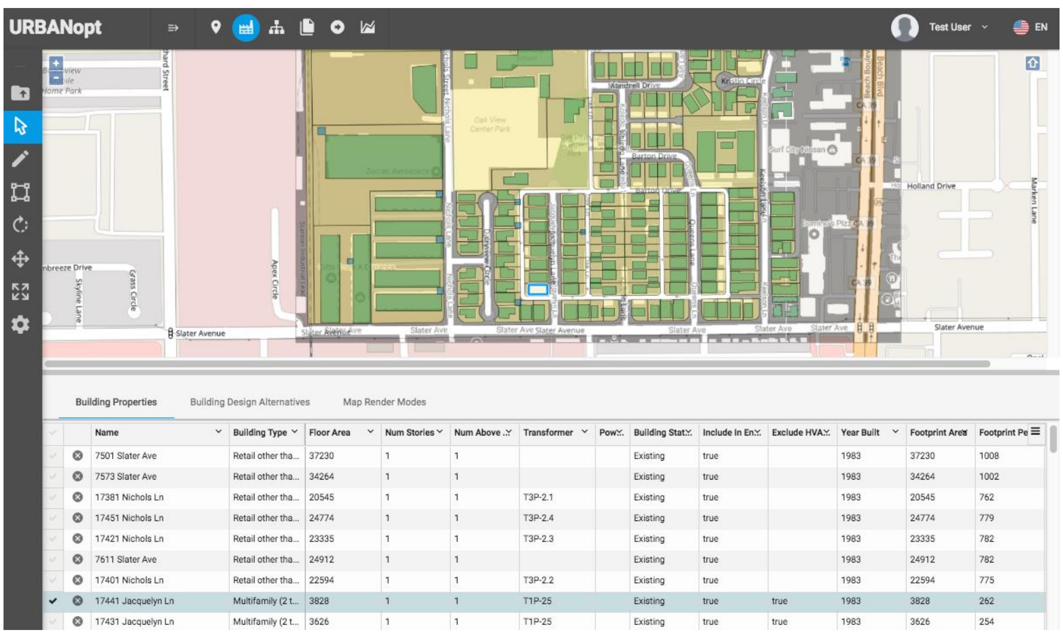
Source: University of California, Irvine

Energy audits were performed to understand the energy use of the community and assess opportunities for EE retrofits. The audits covered the majority of the school, commercial and industrial areas and a representative sample of the residential housing units. An important finding was that residents use very little heating or cooling due to the mild climate of the community. As part of the community assessment process, energy data was collected for major industrial and commercial loads such as the materials and waste processing facilities (Republic Services) and the Family Resource Center (FRC). Energy models, informed by the audits and other community energy data, were created to more deeply understand the energy use of the community.

This information was used to inform the development of the URBANopt community energy model. The URBANopt user interface (UI) is built around a tabular workflow that allows a user to specify information about the site, buildings, district systems, and design scenarios before progressing to run management and analysis results. The UI was used to capture all community data and scenario specifications for the Oak View project.

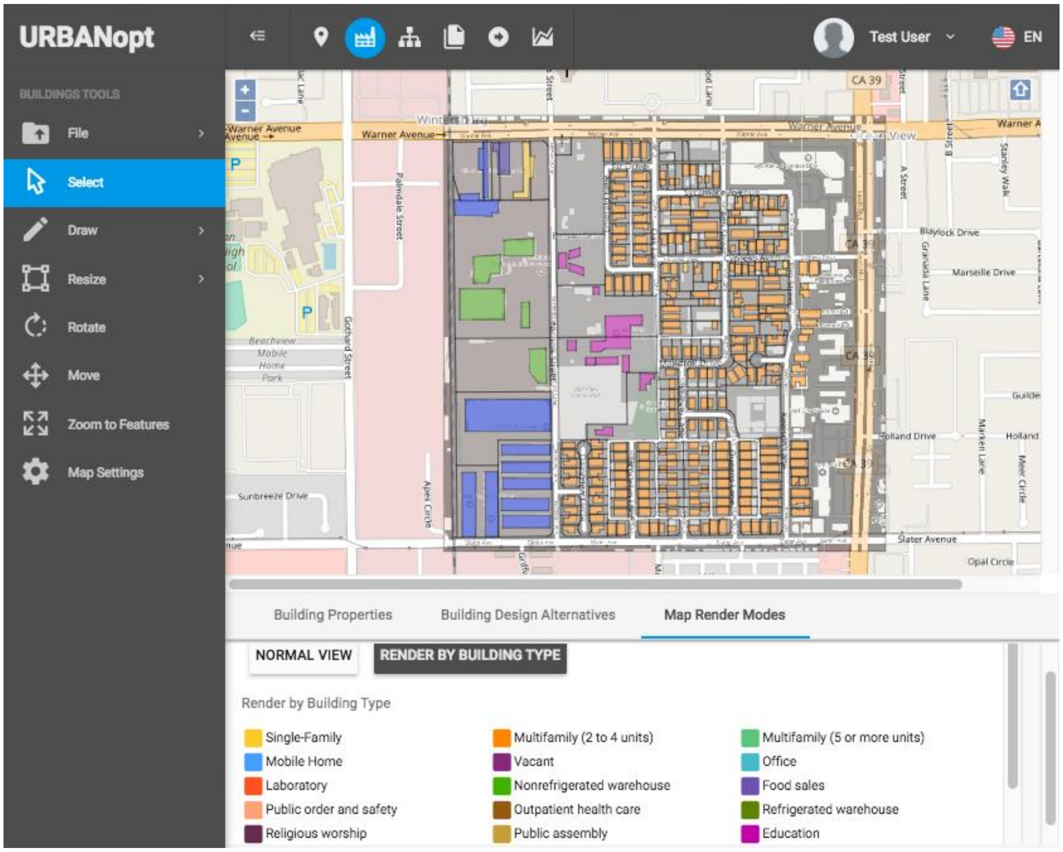
In the case of tax lots, available Orange County shapefile data was converted to GeoJSON and imported to URBANopt as a starting point for the project. Building locations were cross-referenced from address listings to Google Maps, footprints were traced from Google map images and supplemented with building type, vintage, number of floors, and transformer connections from public records and Google Street View images. Figure 25 shows the high level data associated with specific buildings in the community. Once data for all 314 buildings was entered, URBANopt's map rendering capability was used to verify that building types were entered correctly for the project (Figure 26).

Figure 25: Entering Building Data into URBANopt



Source: University of California, Irvine

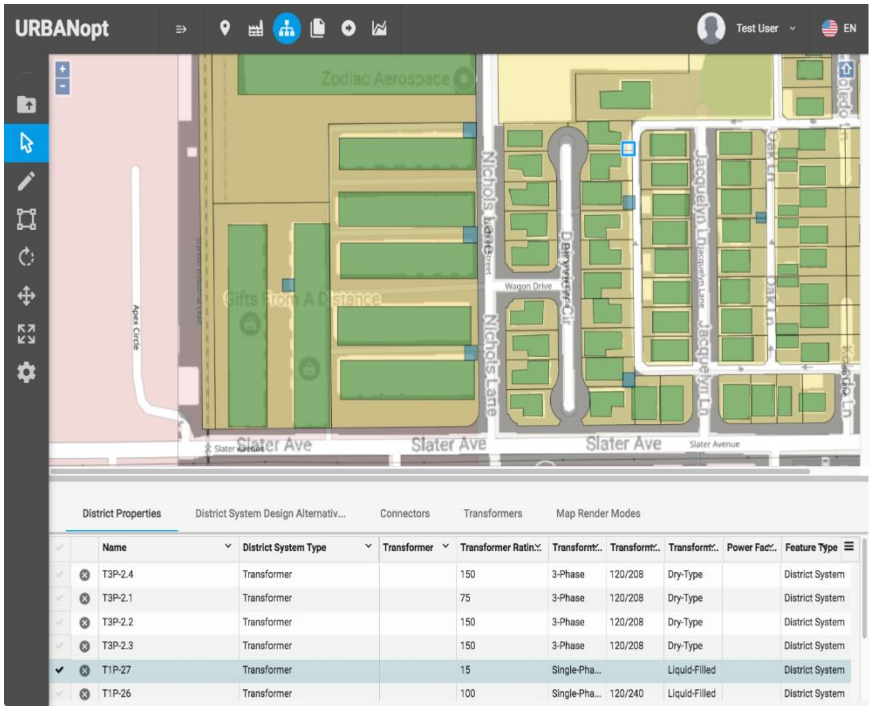
Figure 26: URBANopt UI Rendering of Buildings by Type



Source: University of California, Irvine

One example of district systems tracked by URBANopt are transformers as shown in Figure 27. Transformers are used to aggregate loads from individual buildings, and as connection points for DERs. The transformer rating is a key input utilized by transformer load post-processing reports to identify distribution network pinch points and critical days of the year where load and community generation are misaligned – suggesting different distribution network topologies or storage deployment locations. URBANopt is also intended to analyze districting heating and cooling systems with associated pipe runs, as well as community solar PV. Neither capability is being used at the time this paper was written, but community-scale PV and storage is an anticipated feature of the final Oak View design.

Figure 27: Adding Transformers on the District Systems Tab



Source: University of California, Irvine

Although the URBANopt tool will be used to predict the energy savings benefit for each ECM type, the ECM inputs are input as a percent load reduction. These results must be translated to a number of ECM units installed. In preparation for this, the team estimated the number of lighting fixtures and plug load systems within the community. These estimates were based on site visits and energy audits. The lighting estimate by sector and lighting fixture type is shown in Table 3. Plug load ECMs considered in this work consist primarily of EnergyStar refrigerator and clothes washers, and advanced power strips. Table 4 shows the estimated number of plug load appliance opportunities within the residential sector.

Table 3: Lighting Type and Count by Building Sector

Sector	A19	Canned Light	2' T8	4' T8	Wall Pack	Flood Light	PAR Flood Lamps	High Bay
Application	Interior/ Exterior	Interior	Interior	Interior	Exterior	Exterior	Exterior	Interior
Residential	15,250	30	0	150	825	60	20	0
Commercial	50	0	25	3,800	100	0	0	0
Industrial	0	0	0	2,950	75	40	0	125
Community	15,300	30	25	6,900	1000	100	20	125

Source: University of California, Irvine

Table 4: Residential Plug Load Product Count

Product	Residential Product Count
Advanced Power Strips (APS)	3,377
ENERGY STAR® Refrigerators	1,097
ENERGY STAR® Clothes Washers	315

Source: University of California, Irvine

The commercial plug load retrofit consists of installing advanced power strips within the commercial spaces and engaging standard pre-installed computer software for occupancy controls. Both measures serve to lower energy consumption by reducing unnecessary load while the equipment is not in use. The estimated number of APS for the commercial sector of the community is 380 and the estimated total number of computers for software configuration is 190.

Oak View Energy Technologies

Part of the process of developing an AEC design is selecting which technologies to include in the AEC design process. This consists of determining which EE measures to include in the design. The section details these technologies.

Energy Conservation Measures

Energy conservation measures were selected on the ability of the technology to reduce energy needs of the community to meet the end use requirements. These measures also included technologies, methods, and upgrades that have the potential to improve quality of life within the community through improving indoor and outdoor ambient air quality and temperature.

Lighting Technologies

The ECM assumed for lighting is to replace non-LED lights with LEDs. URBANopt uses a lighting efficiency measure titled “Reduce Lighting Loads by Percentage” to simulate this particular. The measure reduces lighting power density of whole building by percentage

Residential buildings were assumed to have a 75 percent reduction in lighting energy end use. An energy audit conducted by Altura Associates to typical residential buildings in the Oak View community indicates that non-LED lights, including incandescent, halogen and compact fluorescent, are common and hence there is an opportunity to standardize LED technology throughout the community. According to Department of Energy, residential LEDs, especially products rated by ENERGY STAR, use at least 75 percent less energy and last 25 times longer than incandescent lighting [20]. ENERGY STAR states that certified LED bulbs use 70 percent to 90 percent less energy compared to traditional bulbs and last 15 times longer [21]. As a result, an energy reduction of 75 percent was selected for use in applying LED ECM to the residential sector.

For commercial and industrial buildings, 45 percent reduction was assumed except for Zodiac Aerospace (17311 Nichols Lane), which was retrofitted recently. Commissioning was conducted on one of the commercial buildings in Oak View community, FRC community center (17261 Oak Lane). Table 5 presents the specifications of the fluorescent tube mainly used in the building and the replacement LED tube found online. The lighting power reduced about 45 percent by switching from fluorescent to LED lights.

Table 5: Lighting Tube Performance Comparison

	Lights Used in Building	Replacement Product
Model No.	SYLVANIA-22167	LEDT-1003D
Type	Fluorescent	LED
Bulb Shape	T8	T8
Color Temperature Kelvin	4100	4100
Lumens	2600	2000
Wattage (Watts)	28	15

Source: University of California, Irvine, [22], [23]

For industrial high bay luminaire, USDOE presents that luminous efficacy (LE), which is measured in lumens per Watt (lm/W), can vary from 100 to 148 depending on the efficiency of luminaire models, indicating an approximate reduction of 45 percent by switching to more efficient models [24]. Based on this information, 45 percent lighting reduction was applied.

Plug Load Reductions

ECM to reduce plug load energy consumption is a combination of power management, advanced power strips, brightness adjustment and improvement of occupant behavior. URBANopt uses a measure titled “Reduce Plug Load by Percentage” to model plug load reductions due to plug load ECMs. The measure reduces plug load power density of whole building by percentage.

The California Utilities Statewide Codes and Standards (CUSCS) team conducted a literature review on plug load energy usage, including the power consumption of appliances under different modes (on, standby, off), the frequency of various plug loads in US residences and the duty cycles (i.e. percent of time spent in on, standby, or off modes) [25]. The nationwide frequency was assumed to be a sufficient proxy for the frequency in California. Power consumption of each appliance under different modes were then calculated and summed to multiply the frequency of appliances to obtain the total plug load power of a household based on CUSCS data as shown in Table 6. The refrigerator power wattage was based on a product used in a household in the community and the frequency was based on Residential Energy Consumption Survey (RECS) conducted by Energy Information Administration (EIA) [26,27].

CUSCS team assumed that programmable circuits (potentially smart strips) would be used so that when household members are asleep or absent, electronic devices would be turned off and potential power savings achieved in aggressive and average scenario are presented in Table 6. [25].

Table 6: Household Appliance Power Consumption

	Power Consumption by Mode (W)			Appliance Duty Cycle			Power Consumption by Duty Cycle (W)					
Appliances	on	standby/ sleep	off	on	standby/ sleep	off	on	standby/ sleep	off	Total (W)	Frequency in US Household	Household Total (W)
Personal computer	75	4	2	33.00%	4.00%	63.00%	24.75	0.16	1.26	26.17	78.00%	20.4126
Monitor	42	1	1	21.00%	10.00%	69.00%	8.82	0.1	0.69	9.61	78.00%	7.4958
Notebookcomputer	25	2	2	27.00%	11.00%	62.00%	6.75	0.22	1.24	8.21	34.00%	2.7914
DSL modem	5.37	0	1.37	100.00%	0.00%	0.00%	5.37	0	0	5.37	20.00%	1.074
Cable modem	6.25	3.85	3.84	100.00%	0.00%	0.00%	6.25	0	0	6.25	20.00%	1.25
Wi-fi router	5.37	0	1.37	100.00%	0.00%	0.00%	5.37	0	0	5.37	40.00%	2.148
Multi-function device, inkjet	15.2	9.1	6.2	3.00%	7.50%	89.50%	0.456	0.6825	5.549	6.6875	45.00%	3.009375
Printer, inkjet	4.9	0	1.7	1.50%	0.00%	98.50%	0.0735	0	1.6745	1.748	45.00%	0.7866
Set top box, cable	16	0	15	31.00%	0.00%	69.00%	4.96	0	10.35	15.31	67.00%	10.2577
Set top box, satellite	15	0	14	37.00%	0.00%	63.00%	5.55	0	8.82	14.37	61.00%	8.7657
Personal video recorder	27	0	27	24.00%	0.00%	76.00%	6.48	0	20.52	27	1.70%	0.459
Cordless phone	4.2	3.4	2.5	4.00%	8.00%	88.00%	0.168	0.272	2.2	2.64	108.00%	2.8512
Videogame systems	36	36	1	4.60%	6.40%	89.00%	1.656	2.304	0.89	4.85	55.00%	2.6675
Home theater in a box	38	34	0.6	18.00%	8.00%	74.00%	6.84	2.72	0.444	10.004	22.00%	2.20088
Compact stereo	23	16	7	9.50%	8.00%	82.50%	2.185	1.28	5.775	9.24	66.00%	6.0984
Component/rack stereo	45	43	3	18.00%	8.00%	74.00%	8.1	3.44	2.22	13.76	45.00%	6.192
DVD player	14	11	2.9	3.00%	10.00%	87.00%	0.42	1.1	2.523	4.043	104.00%	4.20472
TV	192	0	4	22.00%	0.00%	78.00%	42.24	0	3.12	45.36	230.00%	104.328
Radio	2	0	1	5.00%	0.00%	95.00%	0.1	0	0.95	1.05	49.00%	0.5145
Power speakers	6	4	2	8.00%	23.00%	69.00%	0.48	0.92	1.38	2.78	29.60%	0.82288
Portable stereo	6	5	1.8	6.00%	13.00%	81.00%	0.36	0.65	1.458	2.468	34.80%	0.858864
Refrigerator	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	77.7	128.00%	99.456
											Total	288.64512

Source: University of California, Irvine, [25], [26], [27]

As shown, average usage scenario results in a reduction of 56.06 watts per dwelling unit. In the OpenStudio models of residential buildings, the plug load power density is 0.5 watts per square feet. The area of a typical dwelling unit in the models is about 1000 square feet. Therefore, the plug load power in the models is 500 watts. Assuming statewide average usage scenario will result in a reduction of about 10 percent. In addition, Parker et al. presented that providing instantaneous feedback on electric demand to households would lead to 10-15 percent reduction in overall energy based on past studies [28].

Replacing all plug loads with ENERGY STAR certified products could lead to greater savings in energy, assuming all existing plug loads in the community are not ENERGY STAR certified and average energy savings are achieved from ENERGY STAR products replacement as shown in Table 7. [29]. This results in roughly 20 percent plug load energy reduction. If this method is coupled with the power management method proposed by CUSCS shown in Table 8 and assume same percentage of power can be reduced for ENERGY STAR plug loads, a 35 percent reduction in plug loads power can be achieved. Therefore, 35 percent was chosen as the input for plug load reduction measure.

Table 7: Plug Load Energy Savings

Appliances	Statewide Average Usage Scenario (Watts)
Personal computer	1.56
Monitor	0.78
Notebook computer	0.68
DSL modem	1.07
Cable modem	1.25
Wi-Fi router	2.15
Multi-function device, inkjet	2.37
Printer, inkjet	0.57
Set top box, cable	10
Set top box, satellite	8.54
Personal video recorder	0.46
Cordless phone	3.22
Videogame systems	1.4
Home theater in a box	0.87
Compact stereo	4.62
Component/rack stereo	3.01
DVD player	3.02
TV	9.2
Radio	0.49
Power speakers	0.59
Portable stereo	0.63

Source: University of California, Irvine, [25]

Table 9 presents the type of buildings in school commercial sector. In New Buildings Institute's guide for plug load best practices, low- and no-cost ECMs can reduce plug load energy use by 40 percent in commercial buildings (Figure 28 [30]). Many electronic devices are engineered to run at different modes such as "active," "idle" and "sleep." Completely turning off electronic equipment that is not used helps save energy because devices in idle mode often unnecessarily consume large amounts of energy. Load-sensing power strips using master/slave approach can be set so that when one device is turned off, all devices connected to the strip will also be turned off. Occupancy-sensing power strips turn electronic devices on and off by detecting presence or absence of users.

Table 8: Energy Star Savings

Appliances	Household Total (W)	ENERGY STAR Average Savings	Household Total After ENERGY STAR Replacement(W)
Personal computer	20.4126	0.00%	20.4126
Monitor	7.4958	25.00%	5.62185
Notebook computer	2.7914	0.00%	2.7914
DSL modem	1.074	20.00%	0.8592
Cable modem	1.25	20.00%	1
Wi-Fi router	2.148	20.00%	1.7184
Multi-function device, inkjet	3.009375	30.00%	2.1065625
Printer, inkjet	0.7866	30.00%	0.55062
Set top box, cable	10.2577	25.00%	7.693275
Set top box, satellite	8.7657	25.00%	6.574275
Personal video recorder	0.459	0.00%	0.459
Cordless phone	2.8512	40.00%	1.71072
Videogame systems	2.6675	0.00%	2.6675
Home theater in a box	2.20088	70.00%	0.660264
Compact stereo	6.0984	70.00%	1.82952
Component/rack stereo	6.192	70.00%	1.8576
DVD player	4.20472	45.00%	2.312596
TV	104.328	27.00%	76.15944
Radio	0.5145	0.00%	0.5145
Power speakers	0.82288	0.00%	0.82288
Portable stereo	0.858864	0.00%	0.858864
Refrigerator	99.456	9.00%	90.50496
Total	288.645119	N/A	229.6860265

Source: University of California, Irvine. [29]

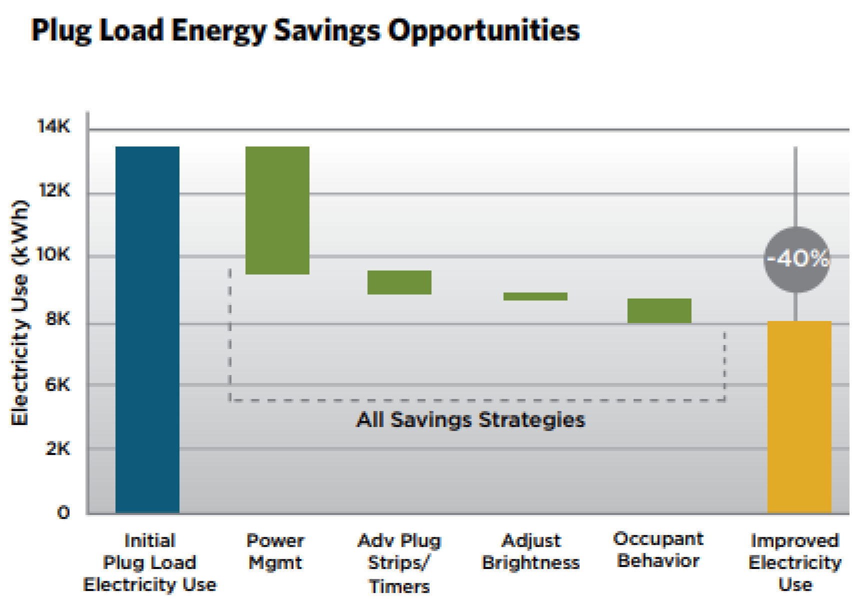
For computer monitors, brightness has the biggest impact on energy consumption and is often set too high. Power management reduces energy consumption by approximately 30 percent, while combining advanced plug strips, brightness adjustment, and occupant behavior control reduces energy consumption by 10 percent as shown in Figure 28. A conservative option of 30 percent plug load reduction was applied to schools and the family resource center, assuming power management would not be executed to maximum potential. For the rest of the buildings, 10 percent was applied, assuming that a certain degree of power management already existed.

Table 9: Types of Buildings in School Commercial Sector

Address	Building Type
17341 Jacquelyn Lane	Child Care Center
17251 Oak Lane Library A	Library
17251 Oak Lane Library B	Library
17131 Emerald Lane Preschool A	School
17131 Emerald Lane Preschool B	School
17175 Emerald Lane A	School
17175 Emerald Lane B	School
17241 Oak Lane Elementary A	School
17241 Oak Lane Elementary B	School
17261 Oak Lane FRC	Family Resource Center
7572 Warner Avenue	Gym
7611 Slater Avenue	Warehouse

Source: University of California, Irvine

Figure 28: Plug Load Energy Saving Opportunities of Commercial Buildings



Source: University of California, Irvine, [30]

Compressed-air systems are present in the automotive service (7582 Warner Avenue), the vehicle shop in Republic Services (17121 Nichols Lane G) and Zodiac Aerospace (17311 Nichols Lane). Saidur et al. analyzed energy saving potential of compressed-air systems and found that energy saving potential could be as high as 32.9 percent through a combination of ECMs including renewal or replacement of equipment [31]. With respect to cost and practicality, reducing air leaks was considered as the only feasible ECM and would lead to 16 percent energy savings, according to Saidur et al. Compressed-air system loads were assumed to be dominant in the automotive service and vehicle shop and hence a 15 percent plug load reduction in whole building was assumed. Zodiac Aerospace (17311 Nichols Lane) is a manufacturing facility with an office, and the exact energy usage breakdown of its plug loads remains unclear. Fifteen percent plug load reduction was assumed as the result of combining office plug load and compressed-air system ECMs.

Table 10: Republic Services Buildings

17121 Nichols Lane Republic	Facility Purpose
A	R&D office, Clean Natural Gas fueling
B	Municipal Solid Waste Sorting
C	Material Recovery Facility
D	Hazardous Waste
E	Construction & Demolition
F	Storage
G	Vehicle Shop

Source: University of California, Irvine

In MSW sorting (17121 Nichols Lane B), MRF (17121 Nichols Lane C) and C&D (17121 Nichols Lane E), belt conveyor systems are used to transfer waste and were assumed to dominate plug load energy consumption in these buildings. Zhang et al. found that the optimal control strategy could reduce belt conveyor system energy consumption by 5.38-15.5 percent [32]. Five percent of plug load reduction was applied as the conservative option.

For the hazardous waste collection center (17121 Nichols Lane D) and the storage building (17121 Nichols Lane F), using advanced plug strips was the assumed ECM (Figure 28) and 5 percent of plug load reduction was applied.

Wall and Roof Insulation

This ECM replaces insulation materials of walls and roofs in the buildings to comply with the California Title 24 2016 standard. URBANopt uses the measures “Set R-value of Insulation for Exterior Walls to a Specific Value” and “Set R-value of Insulation for Roofs to a Specific Value.” These measures specify the R-values of insulation materials for exterior walls and roofs in the whole model.

The 2016 Title 24 standards require wood-framing structure low-rise residential buildings to be insulated with materials of R-13 and R-22 thermal resistance or greater for walls and roofs [33]. The team assumed more effective insulation could be installed, up to an R-30 improvement.

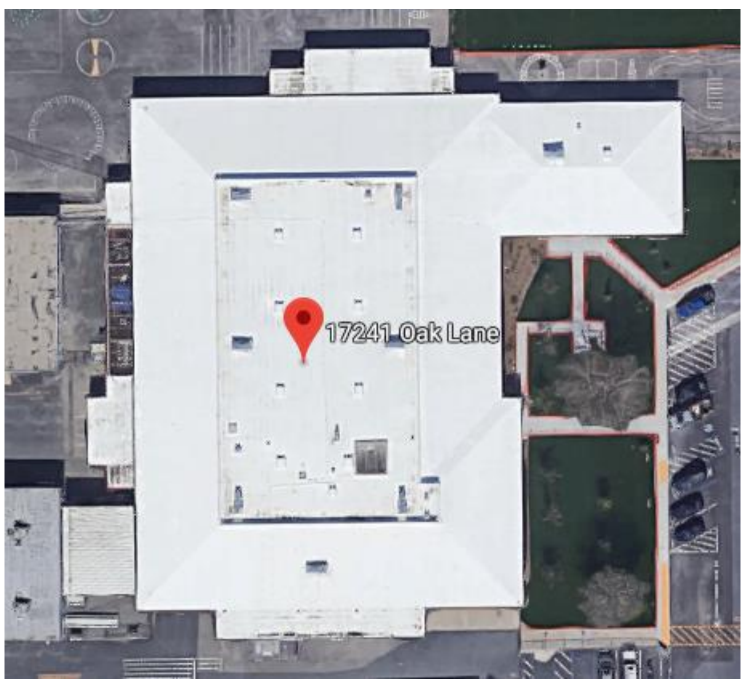
Cool Roof Replacement

Cool roofs are designed to maintain a lower temperature at the roof surface under sunlight than traditional roofs [34]. There are different kind of cool roofs but only cool roof coatings, which contain white or special reflective pigments that reflect sunlight, are considered as the

ECM with respect to cost and practicality. OpenStudio measure “Change Roof Thermal Properties” was applied to simulate cool roof coating effects. It applies a multiplier to original solar absorptance values of all the roof materials in OpenStudio models.

Parker et al. chose a strip mall as a project test site and measured the roof’s solar reflectance before and after applying the cool roof coating [35]. The uncoated metal roof had a solar reflectance of 29.6 percent while the coated roof had a reflectance of 77.4 (±6.0) percent. Converted solar absorptance of the coated roof is 22.6 percent. The roof materials in OpenStudio models have a solar absorptance of roughly 0.7 (70 percent), so a multiplier of 0.35 is determined to model cool roof coating based on the study of Parker et al. The highest initial solar reflectance in the list is 0.94 [36]. The highest average of the initial and after-three-year solar reflectance is about 0.9, which is 0.1 absorptance. Using such a product yields a multiplier of 0.14 for solar absorptance. In this case, a multiplier of 0.35 was eventually applied as a conservative choice. A few buildings in the school commercial sector were exempted because cool roofs were already applied. Figure 29 shows 17241 Oak Lane on Google map. Cool roof coating was already applied based on commissioning, as can be seen in the figure. Other buildings without cool roof measures applied were assumed to be similar to 17241 Oak Lane.

Figure 29: Oak View Elementary School (17241 Oak Lane)



Source: University of California, Irvine

Space Infiltration Reduction

This ECM aims to reduce space infiltration by weatherization through the sealing of structures. In OpenStudio, measure “Reduce Space Infiltration” was applied to simulate the effect of weatherization. This measure reduces space infiltration in a percentage of the whole building in the models.

For residential buildings, field studies of weatherized homes find that average reductions in air leakage are about 13-40 percent [37]. Thirty percent was chosen as a conservative option and universally applied to the residential buildings.

According to the database of building air leakage measurements maintained by the National Institute of Standards and Technology, the average air leakage of 387 commercial and institutional buildings is 13.1 m^3/ h·m^2 at an indoor-outdoor pressure difference of 75 Pa, which is 0.72 cfm/ft^2 [38]. The 2016 Title 24 Standards require that "manufactured fenestration products and exterior doors shall have air infiltration rates not exceeding 0.3 cfm/ft^2 of window area, 0.3 cfm/ft^2 of door area for residential doors, 0.3 cfm/ft^2 of door area for nonresidential single doors (swinging and sliding), and 1.0 cfm/ft^2 for nonresidential double doors (swinging) [33]." Therefore, the requirement for air leakage is approximately 0.3 cfm/ft^2 for the whole building assuming single doors are the source of the majority of air leakage. This indicates a potential reduction in air leakage for commercial buildings of 0.72 - 0.4 cfm/ft^2, approximately a 60 percent reduction. Younes et el. estimates the percentage distribution of infiltration air leakage and finds that walls, windows and doors contribute to 50 percent of air leakage in the whole building on average [39]. Assuming weatherization is only applied to walls, windows, and doors due to cost and simplicity concerns, this results in a 30 percent infiltration air leakage reduction. Several buildings in the school commercial sector do not have infiltration measures applied because they are newer buildings that already comply with the 2016 Title 24 standard already. 17121 Nichols Lane A is the Republic Service office building and hence a 30 percent infiltration reduction measure was also applied. Other buildings in commercial and industrial sector without infiltration measures applied are open-air or do not have HVAC.

Domestic Hot Water Heater Efficiency

The ECM replaces low-efficiency domestic hot water heaters with ENERGY STAR certified products. OpenStudio measure "Set Water Heater Efficiency, Heat Loss, and Peak Water Flow Rate" was applied to the models to analyze practical hot water heater replacement impact. The measure modifies the thermal efficiency values of hot water heaters in the models.

According to USDOE, a less efficient hot water heater has a thermal efficiency of 80 percent, while an ENERGY STAR certified product has a thermal efficiency of 94 percent and the best available product has a thermal efficiency of 98 percent [40]. The team selected 94 percent thermal efficiency as the conservative choice. Buildings without the measure applied do not have a domestic hot water system.

Distributed Energy Resources

The three types of distributed energy resources considered in this work are solar PV panels, EES, and high temperature fuel cells. Two types of solar PV panels were considered: one with a 0.18 capacity factor and with a capital cost of $2,800 per kW, and one with a 0.21 capacity factor with a capital cost of $4,000 per kW. These values were based on quotes received from different solar providers, who also indicated that building a car shade structure would add $500 per kW to the cost. The EES system was based on a system with an 85 percent round trip efficiency when cycling in a 24-hour period, and a cost of $700 per kWh. This capital cost value was based on industry quotes. The high temperature fuel cell was assumed to have a 65 percent electrical efficiency, and cost $4,000 per kW to install.

Alternative Fuel Vehicles

The main transportation option considered in this project was based on an electric vehicle car sharing model because it was deemed cost-ineffective to purchase electric vehicles for private citizens. Instead, a car share company was included to analyze the community for a car share service using electric vehicles. The electric vehicle used for this study was the Volkswagen eGolf.

Local Electrical Utility Rates

Although the local utility is not an ECM or DER option, the baseline scenario for the community is the current one in which all energy needs are met through utility purchases. Due to the wide variety of building end uses, a variety of utility rates apply to the Oak View community. The cost difference in these rates creates an economic basis for community ownership.

Table 11 shows time-of-use rates applicable to commercial and industrial customers, Table 12 shows time-of-use rates applicable to domestic customers, and

Table 13 show tiered rates applicable to domestic customers. Under domestic tiered rates, baseline usage is approximately 10 kWh per day. Typical domestic customers are automatically enrolled under tiered rates and must opt into time of use rates. Also, if a customer purchases solar PV and exports renewable electricity back to the grid, the export sale under net energy metering occurs at the applicable time-of-use rate less a nonbypassable charge associated with transmission and distribution costs (typically around $0.02 per kWh). Finally, SCE – D – CARE rates are accessible only by customers who income-qualify for discounted electricity rates.

Table 11: Southern California Edison Rates for Commercial and Industrial Customers

Charge Type	SCE TOU-8-A	SCE TOU-8-B	Notes
Summer On-Peak ($/kWh)	0.33512	0.10091	Summer weekdays from 12pm - 6pm
Summer Mid-Peak ($/kWh)	0.1063	0.07401	Summer weekdays from 8am - 12pm or 6pm - 11pm
Summer Off-Peak ($/kWh)	0.05603	0.05603	All other summer times
Winter Mid-Peak ($/kWh)	0.07228	0.07228	Winter weekdays 8am - 9pm
Winter Off-Peak ($/kWh)	0.06155	0.06155	All other winter times
nonTOU Demand Charge($/kW)	18.79	18.79	Applied to monthly maximum demand
Summer On Peak Demand Charge ($/kW)	0	21.79	Applies to monthly maximum summer on-peak demand
Summer Mid-Peak Demand Charge ($/kW)	0	4.11	Applies to monthly maximum summer mid-peak demand

Source: University of California, Irvine

Table 12: Southern California Edison Time-of-Use Rates for Domestic Customers

Charge Type	TOU-D-A	Notes
Summer On-Peak ($/kWh)	0.48	Summer weekdays from 2pm -8pm
Summer Mid-Peak ($/kWh)	0.28	Summer weekdays from 8am - 2pm or 8pm - 10pm, or Summer Weekends from 8am - 10pm
Summer Off-Peak ($/kWh)	0.12	All other summer times
Winter On-Peak ($/kWh)	0.36	Winter weekdays from 2pm -8pm
Winter Mid-Peak ($/kWh)	0.27	Winter weekdays from 8am - 2pm or 8pm - 10pm, or Winter Weekends from 8am - 10pm
Winter Off-Peak ($/kWh)	0.13	All other winter times

Source: University of California, Irvine

Table 13: Southern California Edison Tiered Rates for Domestic Customers

Rate	SCE - D	SCE - D - Care	Notes
Summer T1	0.1746	0.11784	Summer usage up to 100% baseline
Summer T2	0.2462	0.16558	Summer usage between 101% and 400% baseline
Summer T3	0.3466	0.23308	Summer usage above 400%
Winter T1	0.1746	0.11784	Winter usage up to 100% baseline
Winter T2	0.2462	0.16558	Winter usage between 101% and 400% baseline
Winter T3	0.3466	0.23308	Winter usage above 400%

Source: University of California, Irvine

Existing Oak View Energy Infrastructure

As a first step towards modeling the existing electric distribution system, the team performed an initial characterization of the local distribution circuits and substations using SCE's DERiM (Distributed Energy Resources Interconnection Map) [16]. The DERiM ArcGIS© database provided not only the precise geographical location of substations, sub-transmission, and distribution circuits, but also information on the current and projected future load and generation and, most importantly, maximum distributed generation hosting capacity.

Ocean View 66/12 kV Substation

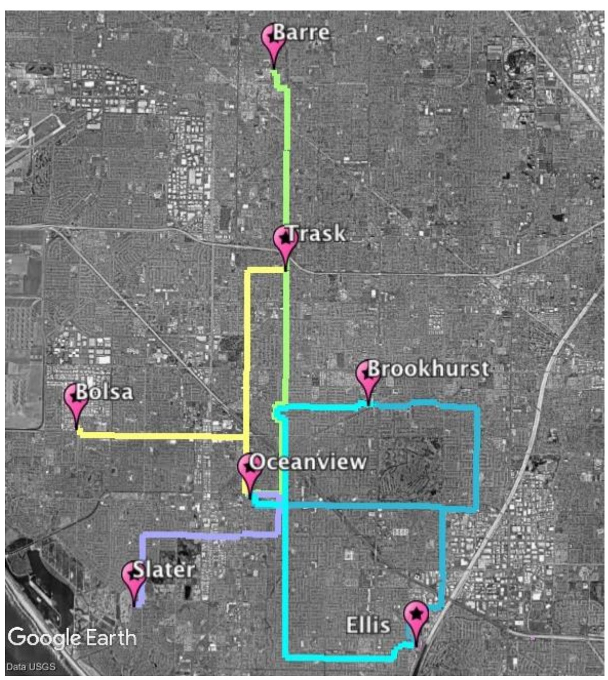
The Ocean View 66/12 kV substation is the B-substation that feeds the Oak View AEC. A B-substation steps-down voltage from the sub-transmission voltage level (typically 66 kV and 115 kV) to the distribution voltage level (typically 4 kV, 12 kV, and 16 kV), The Ocean View Substation is part of the Ellis-A System [16]. Ocean View's projected load for 2017 is 49.20 MW.

Ellis-66/12 kV currently hosts 3.95 MW of DG and still offers capacity for hosting an additional 40.85MW [16]. Figure 30 shows an aerial view of the Ocean View substation as found using *Google Earth Pro©* [41]. There are five 66 kV sub-transmission circuits (Figure 31) that create a network between six neighboring B-substations: Ellis, Bolsa, Barre, Trask, Brookhurst, and Slater.

Figure 30: View of Ocean View Substation

Source: Google Earth

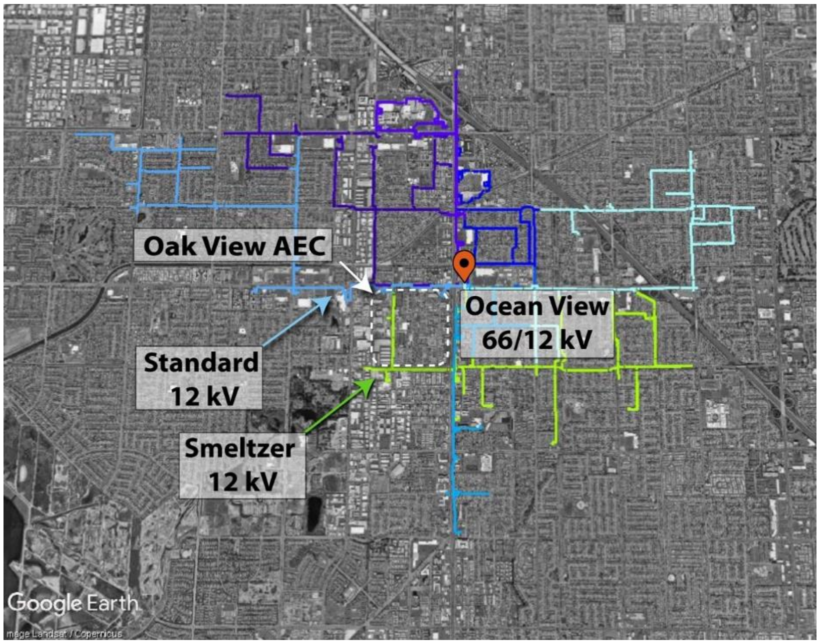
Figure 31: 66 kV Circuits from Ocean View substation.



Source: University of California, Irvine; DERiM circuits exported to Google Earth

Additionally, there are seven 12 kV circuits (Figure 32) that originate from Ocean View and deliver electricity to the Oak View AEC and surrounding area: Smeltzer, Bushard, Beach, Bishop, Heil, Standard, and Wintersburg. The Oak View AEC residential customers are mainly served by Smeltzer 12 kV, whereas the north-west commercial customers are mainly served by Standard 12 kV.

Figure 32: 12 kV Circuits from Ocean View Substation



Source: University of California, Irvine; DERiM circuits exported to Google Earth

Neighboring 66/12 kV Substations

Data gathered from DERiM [16] for existing generation, projected 2018 system load, and remaining generation hosting capacity on the primary 66 kV substations are summarized in Table 14. The Integration Capacity Analysis (ICA) method used to calculate the maximum capacity values (see [42]) defines the amount of distributed generation and aggregated loads the system that may be capable of supporting in its current configuration, that is, without any upgrades needed. The ICA takes into account four criteria with the ultimate goal to maintain system safety and reliability after DER placement:

1. Thermal rating: prevents thermal overloads of conductors, transformers, circuit breakers, and line devices.
2. Power quality/vVoltage: prevents operation outside of the allowable power quality or voltage limits defined by the California Rule 21 and Engineering Standards, which are drawn from American National Standard (ANSI) C84.1 - 2011 Range A. Steady-state voltage is limited to remain in the range between 0.95 p.u. and 1.05 p.u. or 114 to 126 on a 120 V base. Voltage fluctuation limits of 3 percent are used.
3. Protection: ensures existing protection schemes will still promptly detect and respond to abnormal system conditions

4. System flexibility: ensures line transfers and emergency restorations are still performed reliably.

Table 14: 66/12 kV Substations – Existing Generation, Projected Load, and Maximum Remaining Hosting Capacity

Substation	Total Existing Generation (MW)	Projected Load (MW)	Maximum Remaining Generation Integration Capacity (ICA) (MW)
Barre (66/12 kV)	3.35	75.50	108.65
Brookhurst	3.30	44.80	41.50
Bolsa	2.90	40.00	37.10
Ellis (66/12 kV)	3.95	42.50	40.85
Slater	4.42	50.50	51.57
Trask	5.58	86.10	95.22

Source: University of California, Irvine, [16]

The maximum remaining generation ICA values are defined as technology-agnostic, that is, they do not refer to a specific type of distributed generation resource. To calculate the ICA for a specific generation technology (like solar PV), the technology specific hourly per-unit production (the hourly output per MW installed) must be taken into account. Equation (1) is used to calculate the remaining solar PV hosting capacity for the AEC.

$$TS_{ICA}(t) = \frac{TA_{ICA}}{TS_{pu}(t)} \tag{1}$$

Where:

$TS_{ICA}(t)$ = Technology Specific ICA on time t

TA_{ICA} = Technology Agnostic ICA

$TS_{pu}(t)$ = Technology Specific per-unit output on time *t*.

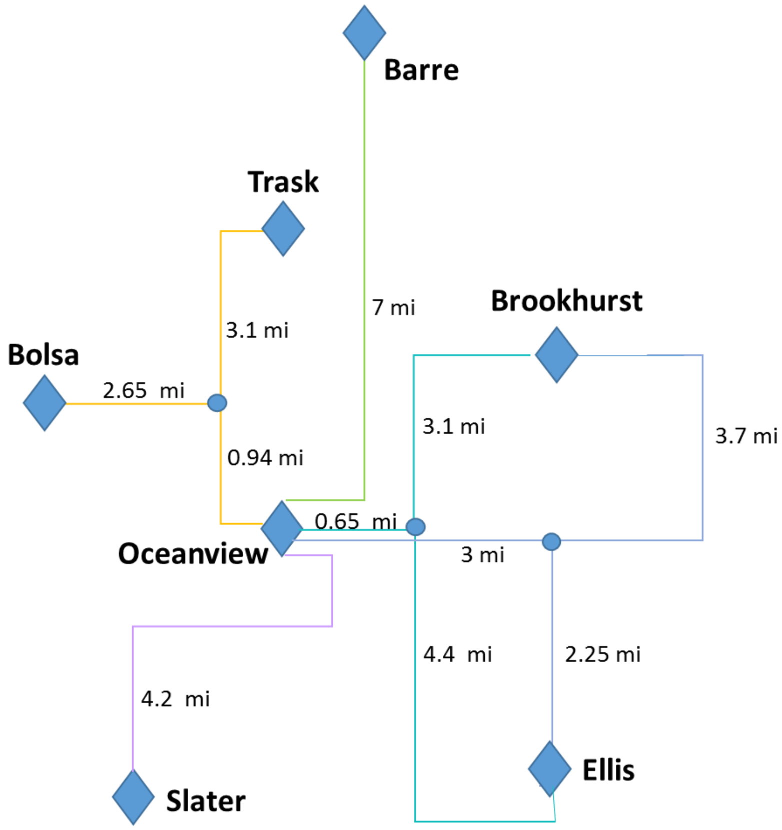
66 kV Sub-Transmission Feeders

The lengths of the 66 kV sub-transmission feeders connecting the substations were measured using Google Earth's geospatial measuring tool and are shown in Figure 33.

12 kV Distribution Feeders

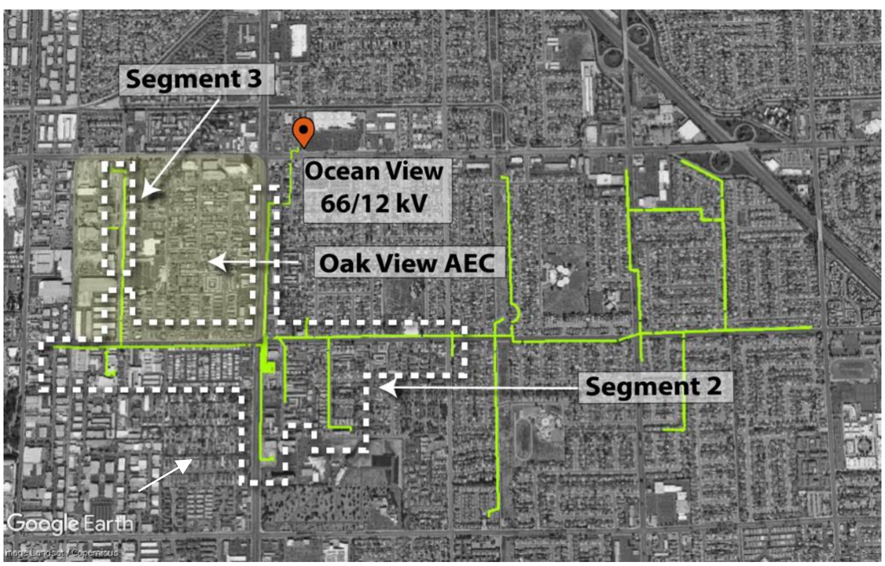
The current generation/load and the remaining generation/loading hosting capacity of the two primary 12 kV distribution feeders, Smeltzer and Standard, were also gathered from DERiM. According to SCE's methodology [42], the ICA values for 12 kV feeders were broken down into specific circuit segments (shown in Table 15 and Table 16). As a starting point for this study, the total ICA assumed is the sum of the ICA values of the individual segments that directly feed the AEC community. For the AEC, these segments 2 and 3 for the Smeltzer circuit (Figure 34), and segment 1 for the Standard circuit. The values assumed for feeder length account for the total circuit length, which was measured using the geospatial measuring tool in Google Earth.

Figure 33: 66 kV Sub-Transmission Feeders and Lengths



Source: University of California, Irvine

Figure 34: Smeltzer 12 kV Distribution Circuit – Segments 2 and 3



Source: University of California, Irvine;DERiM circuits exported to Google Earth

Table 15: DERiM Data for Smeltzer

Existing Generation[1]	0.04 MW		
Projected Load[1]	6.96 MW		
Length[1]	6.29 mi		
ICA Segment	**2**	**3**	**TOTAL**
ICA Generation[2]	3.1	3.1	6.2 MW
ICA Load[3]	0.47	0.47	0.94 MW

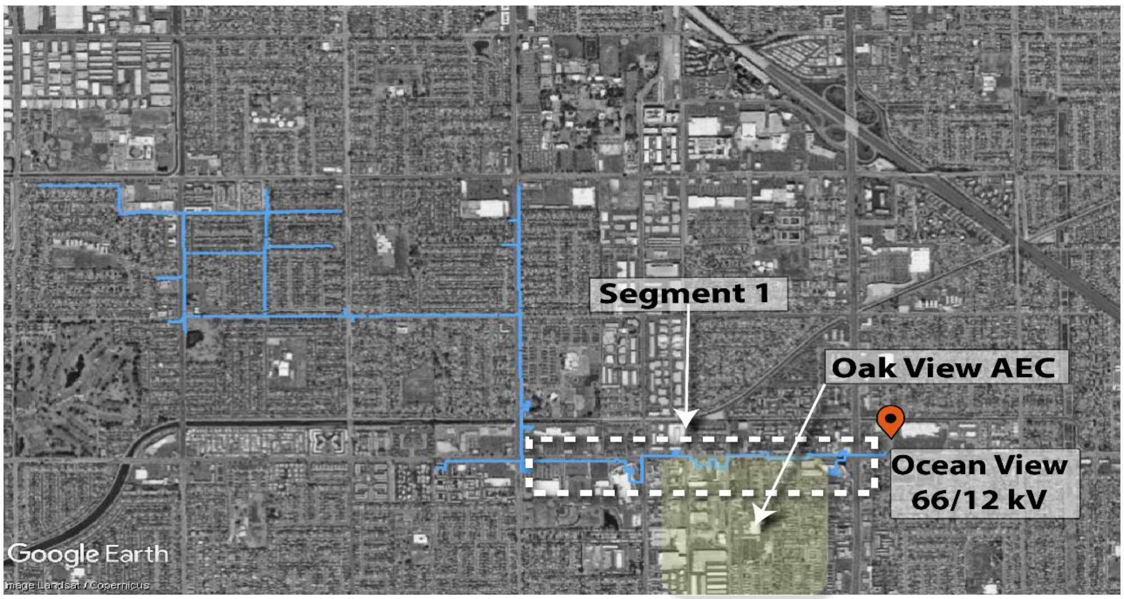
[1] Values for the entire circuit

[2] Maximum technology-agnostic generation hosting capacity for a specific segment

[3] Maximum load hosting capacity for a specific segment

Source: University of California, Irvine, [16]

Figure 35: Standard 12 kV Distribution Circuit – Segment 1



Source: University of California, Irvine; DERiM circuits exported to Google Earth.

Table 16: DERiM data for Standard

Existing Generation[1]	0.76 MW	
Projected Load[1]	10.0 MW	
Length[1]	2.98 mi	
ICA Segment	1	TOTAL
ICA Generation[2]	3.05	3.05 MW
ICA Load[3]	0	0 MW

[1] Values for the entire circuit

[2] Maximum technology-agnostic generation hosting capacity for a specific segment

[3] Maximum load hosting capacity for a specific segment

Source: University of California, Irvine, [16] For the remaining 12 kV feeders, the current installed generation, load, as well as the length was also gathered from DERiM and shown in Table 17.

Table 17: 12 kV Feeders – Existing Generation, Projected Load, and Length

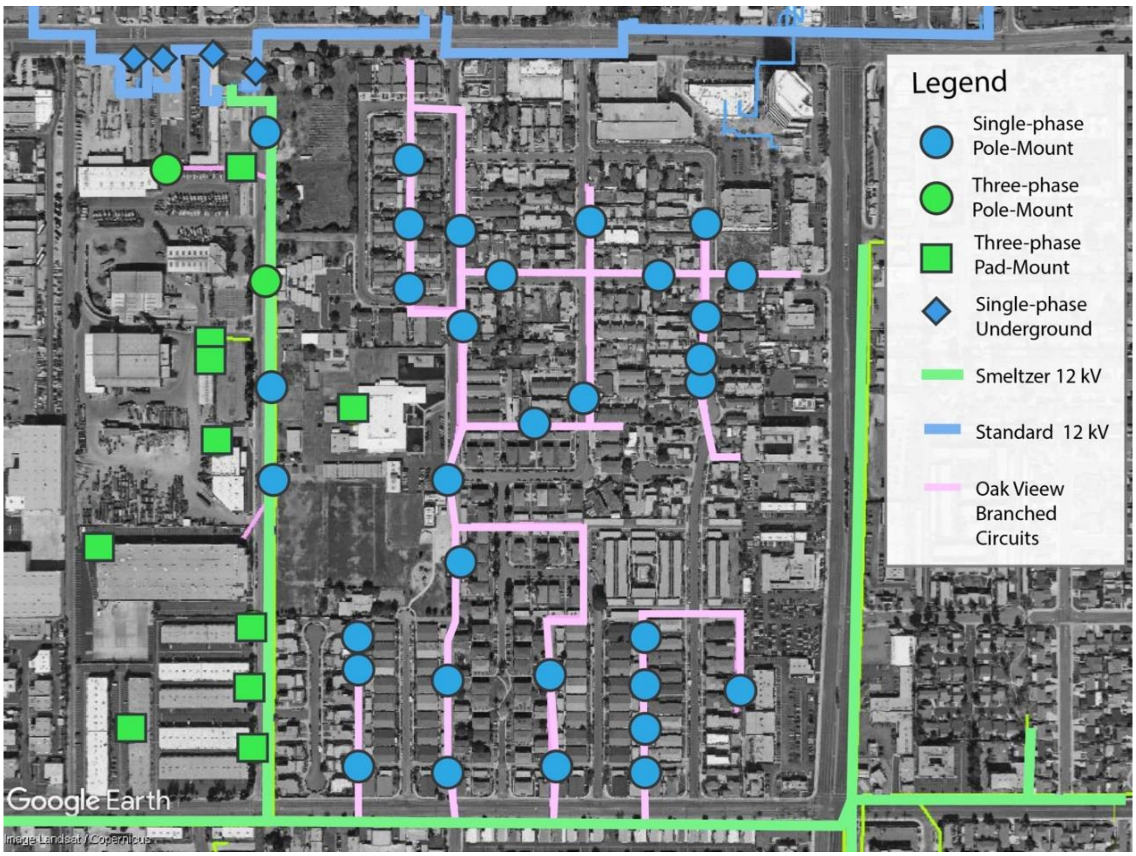
12 kV feeder	Existing Generation (MW)	Projected Load (MW)	Length (mi)
Bushard	0.63	8.25	6.13
Beach	0.12	3.56	2.76
Bishop	0.08	7.96	2.7
Heil	0.66	6.46	4.25
Wintersburg	0.84	8.93	4.1

Source: University of California, Irvine, [14]

Overhead Distribution Circuits and Service Transformers

The geographical location of the overhead 12 kV circuits that branch from both the Smeltzer and Standard feeders and distribute power across the entire Oak View AEC were identified using DERiM and site surveys, and traced on Google Earth. Figure 36 shows the branch circuits in pink, the Smeltzer feeder in lime green, and the Standard feeder in light blue.

Figure 36: Oak View Advanced Energy Community Circuits and Transformers



Source: University of California, Irvine,DERiM circuits exported to Google Earth.

The branch circuits terminate on the primary side of distribution service transformers, which are pole-top, pad-mounted, or underground, depending on the customer type, load, and service voltage. In total, at the Oak View AEC there are 35 single-phase service transformers that feed the residential loads and 14 three-phase service transformers that mainly feed the commercial and industrial loads. All the transformers are also identified and mapped in Figure 36. Examples of pole-top and pad-mounted transformers used in the Oak View community are illustrated in Figure 37.

Figure 37: Oak View Pole-Top Service Transformers

(a) Single-phase 25 kVA

(b) Three-phase 75 kVA pole-top

(c) Three-phase 300 kVA pad mounted

Source: University of California, Irvine

Transformer voltage and load ratings were determined through a survey of SCE and a site visit. The estimated transformer characteristics for the Oak View community are shown in Table 18, along with an estimate of the maximum and minimum loads aggregated by each transformer. While URBANopt is still under development, maximum and minimum community loads were estimated using energy use intensity surveys combined with building area estimates (surveyed on Google Earth) to obtain a given approximated building energy consumption.

The national energy intensity use surveys used as reference include the Residential Energy Consumption Survey (RECS) [43], the Commercial Buildings Energy Consumption Survey (CBECS) [44], and the Manufacturing Consumption Survey (MECS) [45]. Since in this analysis the team was interested in power flows rather than energy totals, once the estimated energy consumption is calculated a "flat" (average) load profile was obtained by dividing the annual energy total by 8,760 hours/year. Then, a peak and valley factor, calculated based on the DOE synthetic load profiles, was applied to these profiles to determine the minimum and maximum hourly load.

Table 18: Oak View AEC Transformer Survey

	Customer	Voltage	Max Load (kVA)	Min Load (kVA)	Rating (kVA)
Single-Phase					
T1	Residential	120/240	19	10	**25**
T2	Residential	120/240	15	9	**25**
T3	Residential	120/240	15	8	**25**
T4	Residential	120/240	14	8	**25**
T5	Residential (Solteros Apt.)	120/240	39	22	**100**
T6	Residential	120/240	37	21	**50**
T7	Residential	120/240	37	20	**50**
T8	Residential	120/240	36	20	**50**
T9	Residential	120/240	25	14	**100**
T10	Residential	120/240	43	24	**50**
T11	FRC + Lib.	120/240	31	17	**37.5**
T12	El School	480/240,120	14	11	**75**
T13	Residential	120/240	12	7	**15**
T14	Residential	120/240	31	17	**50**
T15	Residential	120/240	29	16	**50**
T16	Residential	120/240	42	23	**50**
T17	Residential	120/240	22	12	**25**
T18	Residential	120/240	23	13	**25**
T19	Residential	120/240	40	22	**50**
T20	Residential	120/240	29	16	**50**
T21	Residential	120/240	19	11	**50**

T22	Residential	120/240	9	5	**15**
T23	Residential	120/240	12	6	**15**
T24	Residential	120/240	25	14	**37.5**
T25	Residential	120/240	48	27	**50**
T26	Residential	120/240	27	15	**37.5**
T27	Residential	120/240	76	42	**100**
T28	Child Day Care	120/240	9	5	**15**
T29	Discount Tire	120/240	20	18	**25**
T30	El School (East)	120/240	17	13	**25**
T31	Residential	120/240	57	32	**75**
T32	Residential	120/240	54	30	**75**
T33	Residential	120/240	38	21	**50**
T34	Building Materials	120/240	32	12	**75**
T35	WILLY'S Auto	120/240	50	18	**75**
3-Phase					
T1	Ind. Offices	120/208	50	18	**75**
T2	Ind. Offices	120/208	101	36	**150**
T3	Ind. Offices	120/208	101	36	**150**
T4	Ind. Offices	120/208	142	51	**150**
T5	Zodiac	480Y/277	838	302	**1500**
T6	Pre-School	120/208	34	12	**75**
T7	El School	480Y/277	94	52	**300**
T8	El School	480/208Y,120	20	16	**75**
T9	Republic 1	480Y/277	121	43	**150**
T10	Republic 2	480Y/277	23	8	**50**
T11	Republic 3	480Y/277	326	117	**350**
T12	Republic 4	480Y/277	69	25	**100**
T13	Republic 5	480Y/277	117	42	**150**
T14	HBC + Disc Tire	120/208	114	41	**150**

Source: University of California, Irvine

CHAPTER 8: Oak View Advanced Energy Community Design

This chapter describes the Oak View Advanced Energy Community (AEC) design that resulted from the process described in Chapter 0. The goal for the design was to minimize the cost of energy while approaching zero-net energy (ZNE). While the AEC design is being developed for the entire community, during the implementation phase it is expected that only a portion of the total design can be implemented due to financial constraints.

Critical Community Members

Given the scope of the design, the project team determined the following community members were critical to the AEC design.

- Commercial and industrial businesses: Republic Waste Management Solutions and Zodiac Aerospace were selected due to their projected energy use and importance within the community. As the two largest businesses that also have large industrial loads, it would be impossible to reach ZNE without their involvement. In addition, their involvement in the project provides an avenue through which community dialogue can be improved.
- Educational and community service organizations: Oak View Elementary, Oak View Branch Library, Oak View Family Resource Center, Oak View Preschool, and other organizations that are associated with the Oak View Elementary School are critical community partners due to the renewable potential of the location and the social importance of these organizations within the community. It was critical for the team to develop a relationship with these groups to assist with developing a relationship with the general community.
- Nonprofit housing groups: Orange County Community Housing Corporation, Jamboree Housing, and American Family Housing are leading organizations in the community who strive to improve the quality of life within the community. It was therefore crucial to garner their support for the implementation phase. Not only do these organizations provide a snapshot of typical residential energy use, allow for energy audits to be performed, and provide feedback on design items, they are also dedicated to ensuring that residents receive the benefits of the project.
- Nonprofit energy related groups: Community Action Partnership of Orange County (CAPOC) and GRID Alternatives, along with their nonprofit housing partners, are dedicated to creating benefits that can be passed on to the residents. These groups are essential to implementing an AEC in a disadvantaged community due to their experience in operating in such an area and with delivering supporting funding to similar projects.

After establishing relationships with many of these critical community partners, the team was able to perform energy audits throughout many of the Oak View buildings. The primary audit results indicated that there is extensive potential for lighting and plug load EE measures. In addition, interviews with many community residents indicated that heating and cooling loads are non-existent in the community. Heating loads are non-existent due to a desire to reduce electrical utility bills, non-functional heating equipment, or lack of knowledge on how to operate the heating system. Cooling loads are non-existent because most residents do not have air conditioning equipment. Due to the moderate climate, air conditioning has not been necessary in the Oak View community. In addition, the waste transfer facility also lacks heating and cooling, and the elementary school and Zodiac Aerospace recently experienced extensive renovations in which extensive heating and cooling efficiency measures were implemented. As a result, ECMs associated with heating and cooling were not widely pursued in this work.

The team also found out many residents are very interested in the planting of trees as a possible shading structure. From an energy perspective, this was considered a possible EE measure. However, since trees are likely to primarily reduce cooling in a house, there is little to no energy benefit to the planting of trees. Since the focus of the project is on converting the community into a zero net energy AEC, the team determined that trees would have little to no energy benefits, and omitted them from the design process. A more holistic design process would likely include trees and landscaping needs.

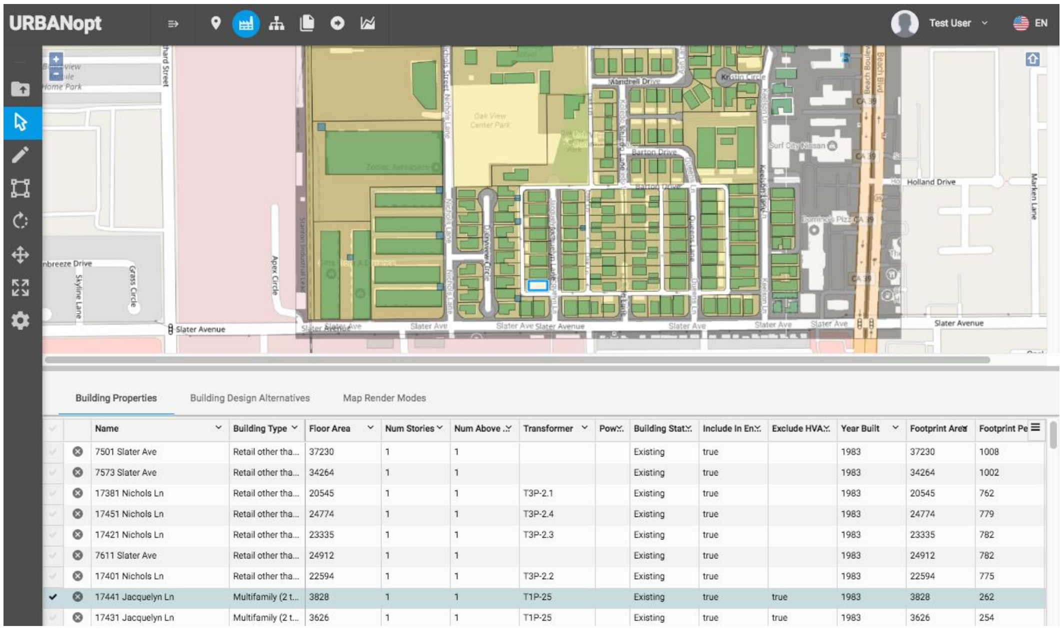
Interviews with residents revealed that many of the Oak View residents receive electrical service through SCE California Alternative Rates for Energy (CARE) rates. The energy audits and site visits revealed that many of the buildings were built between 1960 and 1970.

Oak View Community Baseline Energy Demand

After determining the AEC design goals and project partners, the team applied the URBANopt tool to the Oak View community. Using available tax lot information, Orange County shapefile data was converted to GeoJSON and imported to URBANopt as a starting point for the project. Building locations were cross-referenced from address listings to Google Maps, footprints were traced from Google map images and supplemented with building type, vintage, number of floors, and transformer connections from public records and Google Street View images. Figure 38 shows the high level data associated with specific buildings in the community.

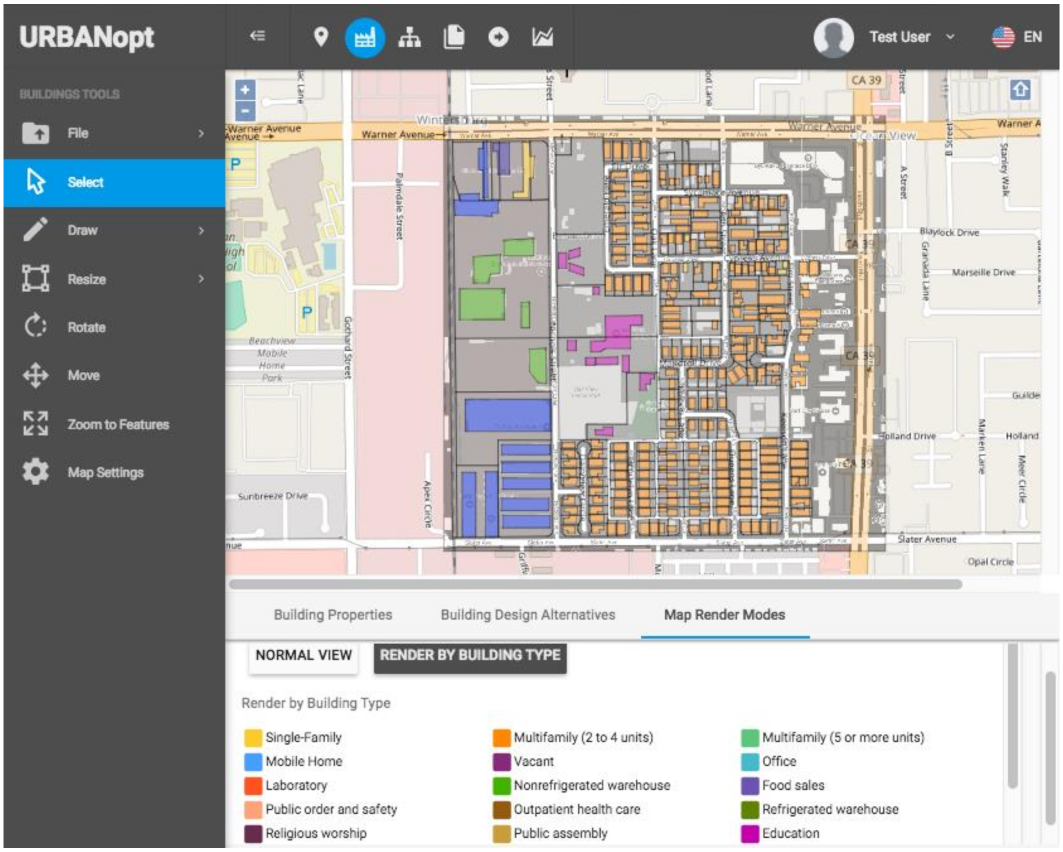
Once data for all 314 buildings was entered, URBANopt's map rendering capability was used to verify that building types were entered correctly for the project (Figure 39). This model was then used to generate the projected energy use for the Oak View community. Note that the building code applied to the automatically generated building models is the USDOE Reference Pre-1980 code. This is due to the apparent vintage of many of the buildings. In addition, the heating and cooling loads were removed from all residential sector buildings.

Figure 38: Oak View Community Information Entered into URBANopt



Source: University of California, Irvine

Figure 39: URBANopt UI Rendering of Buildings by Type



Source: University of California, Irvine

Table 19 shows the annual electrical usage results for the community and individual sectors using the URBANopt model. The table does not include natural gas use. Due to the lack of heating in the residential sector, natural gas usage is small relative to electrical demand (0.5 natural gas GWh annually versus 25.8 electricity GWh annually). Note that the current URBANopt model does not include domestic hot water, resulting in the low natural gas usage. This was not pursued in the current URBANopt iteration due to the focus on electricity under the EPIC program. However, domestic hot water components will be added in future iterations.

Table 19: Projected Baseline Energy Use for the Oak View Community

Building Sector	Annual Electrical Use (GWh)	Average Demand (MW)	Max Demand (MW)	Annual Electricity Costs ($MM/year)	Annual CARE Electricity Costs ($MM/year)
Community	25.80	2.95	4.81	4.42	3.75
Educational	0.33	0.04	0.24	0.08	0.08
Residential	9.70	1.10	1.94	2.06	1.38
Republic Waste Transfer	8.15	0.93	1.80	1.18	1.18
Other C&I	7.61	0.87	1.77	1.10	1.10

Source: University of California, Irvine

In addition to showing annual energy usage, also shows average electrical demand, annual electrical demand, and annual electricity cost. Note that the team does not know the number of Oak View residents on CARE rates. To span all possible scenarios, the cost of electricity was calculated assuming that no Oak View residents received electricity under CARE rates, and when all residents received electricity under care rates. These spanning cases only affect residential rates, as seen in Table 19. The total projected difference between non-CARE and CARE rates results in nearly a $700,000 annual difference in electricity costs for the community. The electrical rates were based on prior work described in [46–50].

Evaluation of Energy Conservation Measure Options

After the establishment of the baseline community energy use, the team performed a case study analysis to assist in comparing project scope, energy savings and implementation cost when different ECMs are considered.[5] Note that step two of the AEC design process was carried out during the selection of ECMs to be included (as described in Chapter 7). The team evaluated 16 different cases with various combinations of ECM and DER measures. Scope combinations were based on the findings of site energy audits, EE best practices, community benefit, and

[5] Case study results were produced during the development of URBANopt. To accomplish the case study objective, specialized building energy models were developed using the OpenStudio/EnergyPlus building energy model simulation tools. This is the same engine that powers URBANopt. The models developed are similar to URBANopt, with the primary difference being the inclusion of domestic hot water in the specialized models built to perform the case studies. These models are only used in Section 0. Note that there was less than 10 percent difference between residential and educational building energy use, but large differences for C&I buildings.

ability to scale implementation to other communities. Energy savings potential was evaluated using energy modeling tools and implementation costs were estimated based on industry standard cost estimating tools in combination with recent vendor quotes. The goal of the case study analysis was to develop a final project design that optimizes criteria for energy reduction potential, renewable energy integration, cost effectiveness, community benefit and advanced technology incorporation. This process also accomplished steps three and four of the AEC design process.

Energy models were built in the OpenStudio platform using information gathered from building vintage, building standards, and on-site energy audits. The ECMs listed in Chapter 7 were assessed. Additionally, DER technologies were assessed including rooftop and canopy solar PV, battery storage and EV charging. These additional technologies were included due to an assumption that the installation budget would be $16 million.

Cost models were generated for each ECM based using RS Means, an industry standard costing tool, and through market research of retrofit technologies. Energy and cost analysis was performed for each ECM to fully assess their potential towards a larger community design. Case studies were developed using the estimates provided by the ECM analysis. The "maximized ECM" case consists of community-wide interior LED retrofits, residential DHW upgrades and commercial and industrial plug and process load (PPL) retrofits.

Table 20 provides a list of the cases, the included scope items, the project cost estimate, and whether a budget constraint was applied or not.

Table 20: Case Study Scope Matrix

Case Study	ECM Item 1	ECM Item 2	ECM Item 3	ECM Item 4	DER Item 1	DER Item 2	Budget Constraint
A	Maximize ECMs				Maximize Solar PV	Battery Storage for PV	N
B	Maximize ECMs				Maximize Solar PV	Battery and EV Shared Use	N
C	Maximize ECMs				Maximize Solar PV		N
D					Maximize C&I Solar PV		Y
E					Maximize Residential Solar PV		Y
F	Maximize ECMs				Rooftop Solar PV		Y
G					Rooftop + Canopy Solar PV		Y
H	All ECMs						Y
I	LED Lighting				Canopy Solar PV		Y
J	LED Lighting				Rooftop Solar PV		Y
K	LED Lighting	Appliances & Plugload*			Canopy Solar PV		Y
L	LED Lighting	Appliances & Plugload*	Envelope Retrofit*		Canopy Solar PV		Y
M	LED Lighting	Appliances & Plugload*	Domestic Hot Water ECMs*		Canopy Solar PV		Y
N	LED Lighting	PPL Retrofits**			Canopy Solar PV		Y
O	LED Lighting	Appliances & Plugload*	PPL Retrofits**	Domestic Hot Water ECMs*	Canopy Solar PV	Battery Storage for PV	Y
P	LED Lighting	Appliances & Plugload*	PPL Retrofits**	Domestic Hot Water ECMs*	Canopy Solar PV	EV Shared Use	Y

***Residential Sector / **Commercial Sector**

Source: University of California, Irvine

Note that incentives have not been included in the cost analysis since the optimal project financing was also under development.

Each case study was assessed based on the case total energy savings, the projected total cost, the reduction in energy costs and the simple payback period.

Table 21 provides results for project cost, annual community energy use, energy and cost savings and payback period. The community baseline energy use is 121,972 MMBTU/year. The energy models predict that baseline energy use is split between electricity (17 GWh/year) and gas use (605,983 therms/year according to the OpenStudio/EnergyPlus models). Note that the largest difference in electricity use was observed in the commercial and industrial buildings, which have process loads that are difficult to predict without extensive energy auditing. Significant electricity use reductions are achieved in most cases, but gas savings are minimal. Note that the project budget is constrained to a maximum of $16 million in cases D through P and not constrained in cases A through C. Project costs range from $4-19 million.

Table 21: Case Study Community Energy Use Summary, Energy and Cost Savings, and Simple Payback Period

Case Study	Total Case Study Cost ($M)	Total Energy Reductions (MMBTU/ year)	Total Energy Reductions from Baseline (%)	Post-Retrofit Community Energy Usage (MMBTU/year)	Total Electric Energy Reductions (MWh/year)	Total Electric Energy Reductions from Baseline (%)	Total Nat. Gas Energy Reductions (therms/year)	Total Electric Nat. Gas Reductions from Baseline (%)	First Year Energy Cost Savings ($M)	Total Energy Cost Reductions from Baseline (%)	Simple Payback Period (years)
A	19.2	52,362	42.9%	69,611	14,632	81.3%	24,382	4.0%	2.2	68.3%	8.6
B	19.2	52,362	42.9%	69,611	14,632	81.3%	24,382	4.0%	2.2	68.3%	8.7
C	17.8	43,130	35.4%	78,842	11,926	66.3%	24,382	4.0%	1.8	55.8%	9.8
D	11.4	22,092	18.1%	99,881	6,475	36.0%	0	0.0%	1.0	29.9%	11.7
E	4.3	8,952	7.3%	113,021	2,624	14.6%	0	0.0%	0.4	12.1%	10.8
F	16.0	33,993	27.9%	87,980	9,248	51.4%	24,382	4.0%	1.4	43.4%	11.4
G	16.0	31,167	25.6%	90,806	9,134	50.8%	0	0.0%	1.4	42.2%	11.7
H	10.8	22,663	18.6%	99,310	3,509	19.5%	106,906	17.6%	0.6	19.2%	17.3
I	16.0	31,630	25.9%	90,343	9,490	52.8%	-7,495	-1.2%	1.4	43.7%	11.3
J	13.9	32,353	26.5%	89,619	9,702	53.9%	-7,495	-1.2%	1.4	44.7%	9.6
K	16.0	27,690	22.7%	94,282	8,396	46.7%	-9,560	-1.6%	1.3	38.6%	12.8
L	16.0	29,897	24.5%	92,076	6,686	37.2%	70,824	11.7%	1.1	32.9%	15.0
M	16.0	28,933	23.7%	93,039	7,829	43.5%	22,222	3.7%	1.2	36.8%	13.4
N	16.0	34,003	27.9%	87,969	10,179	56.6%	-7,290	-1.2%	1.5	46.9%	10.5
O	16.0	33,912	27.8%	88,060	9,282	51.6%	22,426	3.7%	1.4	43.5%	11.3
P	16.0	31,204	25.6%	90,769	8,488	47.2%	22,426	3.7%	1.3	39.9%	12.4

Source: University of California, Irvine

Cost reductions are based on assumed average rates of $0.15/kWh and $0.90/therm. Total energy use reductions range from 7-43 percent and cost reductions range from 12-68 percent. Electricity use reductions range from 15-81 percent and gas use reductions range from 0-18 percent. Simple payback ranges from 8.7-17.3 years.

Through the case study analysis, Case O was found to best meet the criteria for energy reduction potential (28 percent reduction compared to total baseline energy use), renewable energy integration (3.3 MW of solar capacity), cost effectiveness ($1.6 million in energy cost savings and a 44 percent reduction compared to the total, $16 million budget and 11.3 year simple payback), community benefit (scope that is widely spread across all sectors of the community) and advanced technology incorporation (battery storage for load leveling).

Case O scope consists of:

- Residential: interior/exterior lighting retrofit, appliance and plug load upgrades and (DHW) retrofits
- Commercial: interior/exterior lighting retrofit and plug and process load (PPL) reductions
- Industrial: interior/exterior lighting and plug and process load (PPL) reductions
- Other: 3.3 MW of canopy solar and 1.1 MW of battery storage

Subsequent work focused on translating these case study results into the URBANopt platform. The case studies revealed the potential of different combinations of ECMs, but also indicated that a combination of LED lighting and plug load retrofit options would be automatically adopted items for the final AEC design due to a relatively fast payback. Also, the results indicated that installing additional systems beyond the assumed $16 million budget yielded better financial and energy reduction benefits.

Using the results from the Case O study, the ECM properties were input into the URBANopt model. Four individual scenarios were run: 1) baseline, 2) LED ECM only, 3) plug load ECM only, and 4) LED and plug load ECM combined. The results for these scenarios is shown in Table 22.

Table 22: URBANopt Results for LED and Plug Load Energy Conservation Measures Scenarios

Measure	Baseline	LED	Plug Load	LED + Plug Load
Annual Electrical Demand (GWh)	25.82	19.60	24.26	17.99
Reduction from Baseline	0.0%	24.1%	6.0%	30.3%
Average Demand (MW)	2.95	2.24	2.77	2.05
Peak Demand (MW)	4.81	3.74	4.57	3.47
Annual Electricity Costs ($MM/year)	4.42	3.23	4.06	2.86
Annual CARE Electricity Costs ($MM/year)	3.75	2.71	3.49	2.44

Source: University of California, Irvine

Note that the individual ECM energy reduction effects add to the total reduction when both ECMs are applied. Since the heating and cooling loads are not considered, the ECM benefits are additive. In total, the proposed LED and plug load ECMs are projected to reduce electrical use by more than 30 percent, reduce average demand by 0.9 MW, and reduce peak demand by more than 1.3 MW. Total electricity savings are projected to be more than $1 million, resulting in a 35 percent reduction in electricity costs. The mismatch between energy and cost savings is due to more expensive T2 and T3 in the residential being reduced first. Results for each individual sector and demand profile shapes are respectively shown in Table 23 and Figure 41 for the residential sector, Source: University of California, Irvine

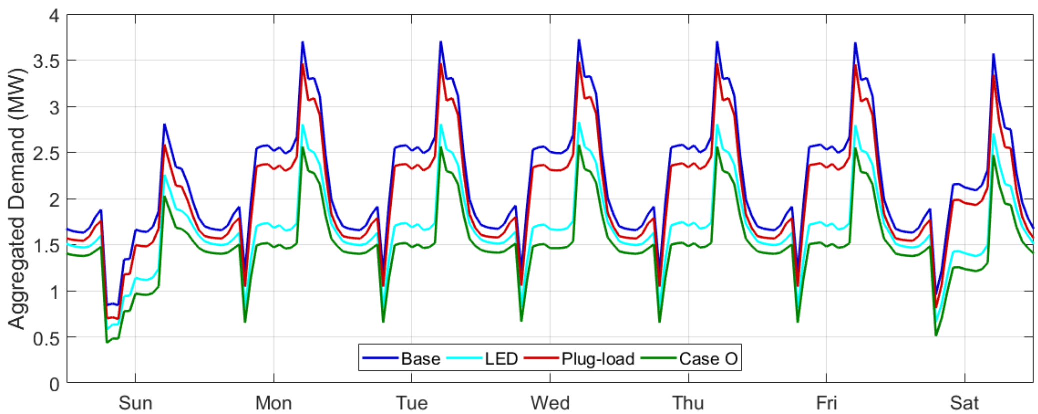
Table 24 and Figure 42 for the educational sector, Source: University of California, Irvine

Table 25 for the Republic waste transfer station, and

Table 26 and Source: University of California, Irvine

Figure 43 for the remaining C&I sector. Figure 40 shows the community electrical demand profile produced by the URBANopt model.

Figure 40: Projected Oak View Electrical Demand Profile for the Baseline, LED, Plug Load, and LED + Plug Load (Case O) Scenarios



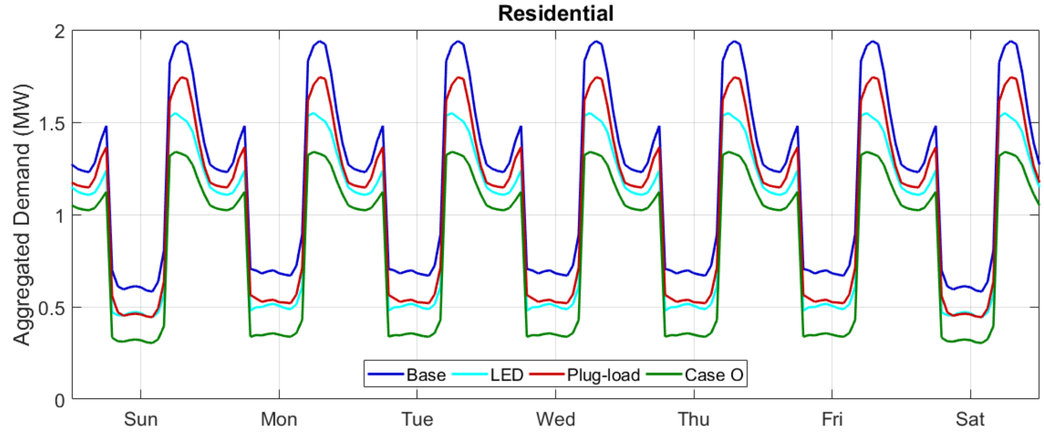
Source: University of California, Irvine

Table 23: URBANopt Residential Sector Results for LED and Plug Load Energy Conservation Measure Scenarios

ECM	Baseline	LED	Plug Load	LED + Plug Load
Annual Electrical Demand (GWh)	9.72	7.82	8.47	6.57
Reduction from Baseline	0.0%	19.6%	12.9%	32.5%
Average Demand (MW)	2.95	2.24	2.77	2.05
Peak Demand (MW)	4.81	3.74	4.57	3.47
Annual Electricity Costs ($MM/year)	4.42	3.23	4.06	2.86
Annual CARE Electricity Costs ($MM/year)	3.75	2.71	3.49	2.44

Source: University of California, Irvine

Figure 41: Estimated Electrical Demand Profile for Residential Sector for Baseline, LED, Plug Load, and LED + Plug Load (Case O) Scenarios



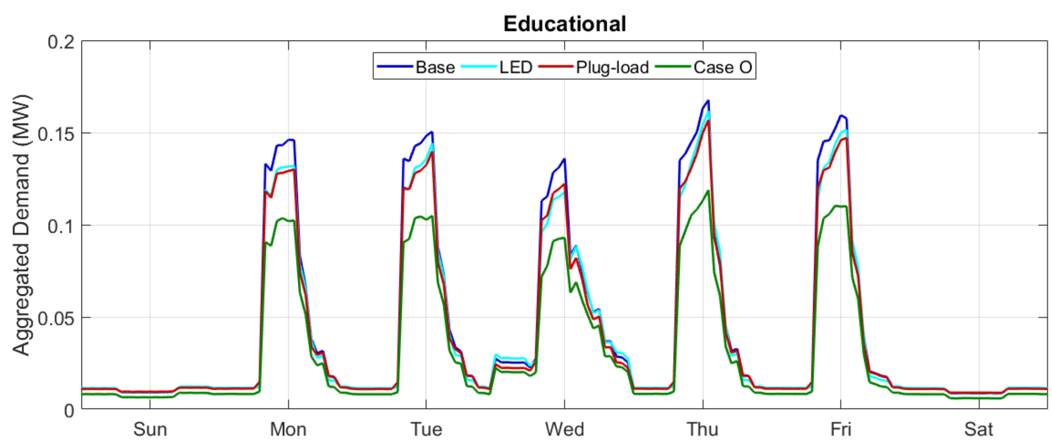
Source: University of California, Irvine

Table 24: URBANopt Educational Sector Results for LED and Plug Load Energy Conservation Measure Scenarios

ECM	Baseline	LED	Plug load	LED + Plug load
Annual Electrical Demand (GWh)	0.33	0.32	0.31	0.25
Reduction from Baseline	0.0%	2.9%	5.8%	25.3%
Average Demand (MW)	0.04	0.04	0.04	0.03
Peak Demand (MW)	0.24	0.24	0.22	0.20
Annual Electricity Costs ($MM/year)	0.08	0.08	0.08	0.06

Source: University of California, Irvine

Figure 42: Estimated Electrical Demand Profile for Educational Sector for Baseline, LED, Plug Load, and LED + Plug Load (Case O) Scenarios



Source: University of California, Irvine

Table 25: URBANopt Waste Transfer Sector Results for LED and Plug Load Energy Conservation Measure Scenarios

ECM	Baseline	LED	Plug load	LED + Plug load
Annual Electrical Demand (GWh)	8.15	6.27	8.00	6.12
Reduction from Baseline	0.0%	23.1%	1.8%	24.9%
Average Demand (MW)	0.93	0.72	0.91	0.70
Peak Demand (MW)	1.80	1.20	1.75	1.15
Annual Electricity Costs ($MM/year)	1.18	0.84	1.16	0.82

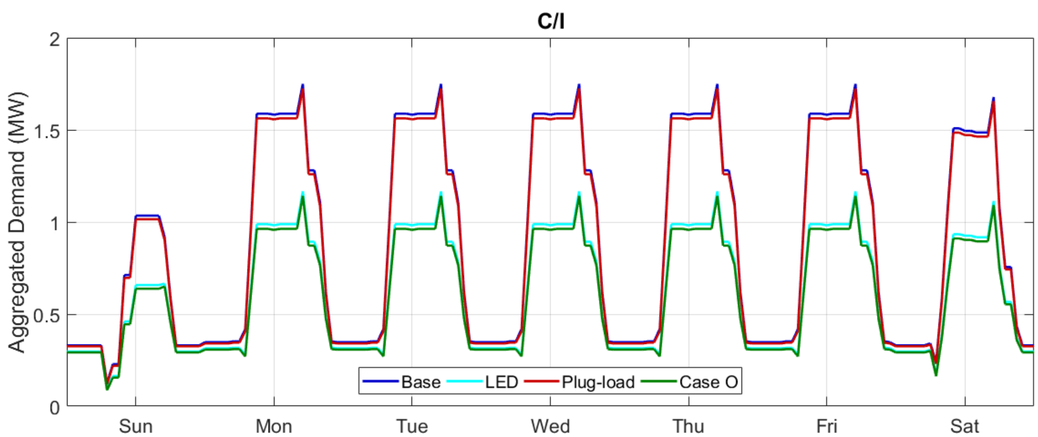
Source: University of California, Irvine

Table 26: URBANopt Commercial and Industrial Sector Results for LED and Plug Load Energy Conservation Measure Scenarios

ECM	Baseline	LED	Plug load	LED + Plug load
Annual Electrical Demand (GWh)	7.61	5.18	7.48	5.05
Reduction from Baseline	0.0%	31.9%	1.7%	33.6%
Average Demand (MW)	0.87	0.59	0.85	0.58
Peak Demand (MW)	1.77	1.17	1.74	1.14
Annual Electricity Costs ($MM/year)	1.10	0.72	1.08	0.70

Source: University of California, Irvine

Figure 43: Estimated Electrical Demand Profile for the Commercial and Industrial Sector for Baseline, LED, Plug Load, and LED + Plug Load (Case O) Scenarios



Source: University of California, Irvine

Based on these energy and cost saving results, the simple payback for each measure was calculated and is shown in Table 27. According to these results, the longest simple payback that can be expected is the residential appliance retrofit, which is projected to pay back in just over 10 years if all residents are on CARE rates. Due to the rapid payback of all ECMs, the LED and plug load retrofits have to be a component in the final AEC design.

Table 27. Final Design Energy Conservation Measures Simple Payback

Measure	Retrofit Cost	Annual Energy Cost Savings (per/year)	Annual Energy Cost Savings - CARE Rates (per/year)	Simple Payback (years)	Simple Payback - CARE Rates (years)
Community-wide LED Retrofit	$630,000	$1,190,000	$1,040,000	0.5	0.6
Residential Appliance Retrofit	$2,620,000	$360,000	$260,000	7.3	10.1
Commercial PPL Retrofit	$21,000	$40,000		0.5	
All ECM	**$3,271,000**	**$1,590,000**	**$1,340,000**	**2.1**	**2.4**

Source: University of California, Irvine

The other ECM items discussed in Chapter 7 were explored. While these items are expected to improve quality of life through improved interior temperature conditions, the various building improvements were found to have no cost or energy savings benefits. These ECMs primarily affect heating and cooling energy use. Since the energy audits and site visits led the team to estimate extremely low heating and cooling loads throughout the community, any ECMs related to maintaining interior temperatures or reducing solar gains are expected to have negligible cost or energy savings benefits. Also, since the domestic hot water ECMs are primarily focused on reductions in natural gas use, these measures are excluded from the current version of the URBANopt model and results. Please note, however, that certain community partners may be capable of installing these ECMs that do not produce cost and energy savings for electrical use within the community. In these cases, the ECMs will be included in the final AEC design.

Additional Advanced Energy Community Technology Evaluation

The prior section examined the use of all ECMs. The results either showed that the ECMs should be adopted (LED and plug load) or that the ECMs will have no electrical cost savings or energy savings potential. The remaining AEC technology items to be considered are the DER technologies, technologies associated with renewable natural gas production, and the car share service.

Distributed Energy Resource Potential

Prior to optimal DER design, the DER potential for each building must be determined. In particular, the maximum solar PV capacity at each building must be determined. Using the solar PV estimation method described in Chapter 4, the team estimated the maximum solar PV capacity for the Oak View community. Under this method, the team considered realistic rooftop constraints, such as the existence of existing roof mounted equipment or exhaust flue ducting, building code at setback requirements, and other structural limitations observed during site visits and energy audits. The total area that can be covered is shown in the aerial image of the Oak View community in Figure 44.

Figure 44: Aerial Image of Maximum Solar Photovoltaic Capacity across Entire Oak View Community

Source: University of California, Irvine

The maximum solar PV capacity assuming a panel efficiency of 18 percent is shown in Table 28. If the maximum capacity were installed, the projected energy production would be approximately 16 GWh, less than the projected 17 GWh used annually after LED and plug load ECM implementation. This shortfall, however, is due to the mismatch between the solar PV capacity in the waste transfer sector and the electrical loads at that location. The maximum solar PV capacity at the waste transfer station is projected to produce 1.6 GWh, much less than the annual electrical demand of 6.12 GWh. To approach ZNE, additional solar PV capacity must be installed elsewhere in the community to offset the industrial loads present in the waste transfer station. Shifting towards higher performance panels would result in sufficient solar PV capacity to achieve zero net electrical energy. However, the change in panel type would also increase costs by a projected $1,000 per kWh.

Table 28: Maximum Solar Photovoltaic Capacity for Oak View Community and Individual Sectors

Community Solar PV Capacity (kW)					
Solar PV Type	**Community**	**Educational**	**Residential**	**Waste Transfer**	**Remaining C&I**
Roof Mount	6579	20	4752	59	1748
Car shade Mount	3598	445	0	956	2197
All	10177	465	4752	1015	3945

Source: University of California, Irvine

Three other solar PV scenarios are presented in Appendix D.

Optimal Distributed Energy Resource Sizing

Using the maximum solar PV capacity for each building, the DERopt model was run to determine optimal DER adoption and placement throughout the Oak View community. Since the ECM analysis showed that LED and plug load ECMs pay back in under ten years, it was assumed that these measures would be adopted, and that the test load for selecting DER would be the Oak View community post ECM integration. At the first, the DERopt model was run to minimize cost. Since there was no requirement to reduce the net electrical energy use in the community, the DERopt model selected to adopt no solar PV or EES since at present the utility provides the lowest cost source of energy.

To achieve the goal of approaching zero net energy, a constraint was added to force net energy use in the community to drop by a percentage of the ECM scenario annual energy use. The DERopt model was run for a 20 percent, 40 percent, 60 percent, 80 percent, 85 percent, 87.5 percent, 90 percent, and 91 percent reduction. The results of the simulations for the entire community are shown in Table 29. Simulation results stop at a 91 percent reduction because further reductions are infeasible. At 91 percent, the maximum solar PV capacity is nearly achieved and there is no other option to reduce net electrical energy use in the community. Note that, when compared to the baseline scenario, or as the community exists today, net electrical use in the community can be reduced by nearly 94 percent.

Table 29: DERopt Simulation Results for Oak View Community

Net reduction from LED + Plug Load (%)	20	40	60	80	85	87.5	90	91
Annual Energy Use (GWh/year)	14.39	10.79	7.20	3.60	2.70	2.25	1.80	1.62
Net Reduction from Baseline (%)	44.3	58.2	72.1	86.1	89.5	91.3	93.0	93.7
Average Demand (MW)	1.63	1.22	0.81	0.43	0.30	0.25	0.20	0.18
Peak Demand (MW)	3.24	3.09	2.97	3.20	2.95	3.00	3.00	3.00
Solar PV (kW)	2152	4316	6491	9416	9434	9712	10007	10091
EES (kWh)	362	896	1305	4702	4564	5213	5703	5521
REES (kWh)	0	71	136	5528	5575	6421	7469	8651
Annual Electricity Cost ($MM/year)	1.71	1.21	0.80	0.42	0.28	0.27	0.28	0.31
Annual CARE Electricity Costs ($MM/year)	2.00	1.58	1.25	0.82	0.69	0.66	0.65	0.67

Source: University of California, Irvine

General results from the DERopt simulations are shown in Table 30.

Table 30: Properties of DERopt Results

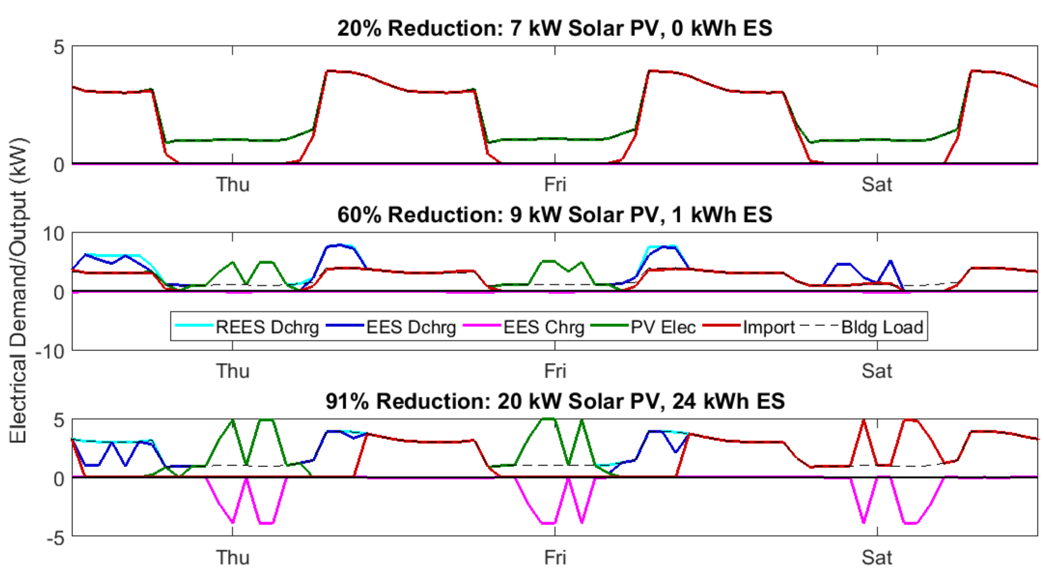
Net reduction from LED + Plug load (%)	20	40	60	80	85	87.5	90	91
Import / Load (%)	91.5	82.2	74.7	70.5	71.2	71.4	71.2	71.3
PV to Building / Load (%)	8.5	17.8	25.3	25.3	24.4	24.5	24.7	24.2
EES Discharge / Load (%)	0.5	1.1	1.8	7.1	7.4	8.7	9.7	9.5
REES Discharge / Load (%)	0.0	0.1	0.2	4.8	5.1	5.0	5.1	5.4
Export / Load (%)	11.5	22.2	34.8	50.8	56.4	59.1	61.5	62.6
PV to Building / PV Production (%)	42.4	44.3	42.0	31.0	28.2	27.4	26.8	26.0
PV NEM / PV to Building (%)	57.6	44.7	40.3	22.1	24.8	23.9	23.1	22.6
PV Wholesale / PV Production (%)	0.0	10.7	17.5	36.6	36.6	37.3	37.4	37.5
PV to REES / PV Production (%)	0.0	0.2	0.3	10.3	10.4	11.4	12.8	13.9

Source: University of California, Irvine

The first row shows the net reduction from the LED and plug load ECM scenario. The second row shows the total reduction in imported electricity versus the total electric load. These results indicate that more than 70 percent of the community electrical demand is met through utility imports even when net electrical energy use has been reduced by 91 percent. In addition, at most, nearly 25 percent of the community electrical demand is met directly from solar PV production, 5.4 percent from solar PV production that was stored for later use, and 10 percent from EES, which was charged by utility imports and solar PV sent to the building. In addition, of the total solar production, 26 percent is sent to the building when net electrical energy is reduced by 91 percent, nearly 60 percent is exported back to the grid, and the remainder is sent to storage. In total, export of electricity is nearly 62 percent of the actual community load at a net electrical energy reduction of 91 percent.

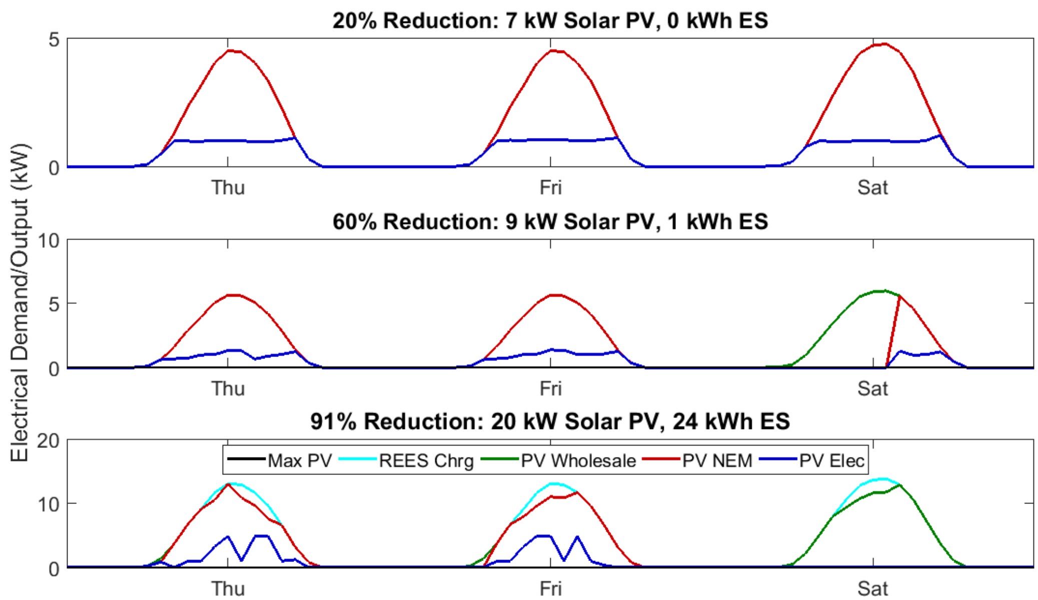
Figure 45 through Figure 50 show examples of DER dispatch and solar PV operation for different buildings in the community when net electrical energy use is reduced by 20 percent, 60 percent, and 91 percent. DERopt generates the optimal dispatch profiles for each building in the community for the entire year. Figure 45 and Figure 46 show DER and solar PV operating at the residential building 17311 Koledo Ln respectively. Figure 47 and Figure 48 show DER and solar PV operating at the educational building located at 17241 Oak Ln respectively. Figure 49 and Figure 50 show DER and solar PV operation at the commercial and industrial building located at 7501 Slater Ave. These figures indicate how DER operation changes as community net electricity use is forced to decrease. This most notable changes are to the adoption and charging of a battery using excess solar and resulting discharge to reduce night time loads, and the shift in from NEM to wholesale export of electricity.

Figure 45: Distributed Energy Resource Operation at 17311 Koledo Ln (Residential) for Three Days when Net Electrical Use is Reduced by 20%, 60%, and 91%



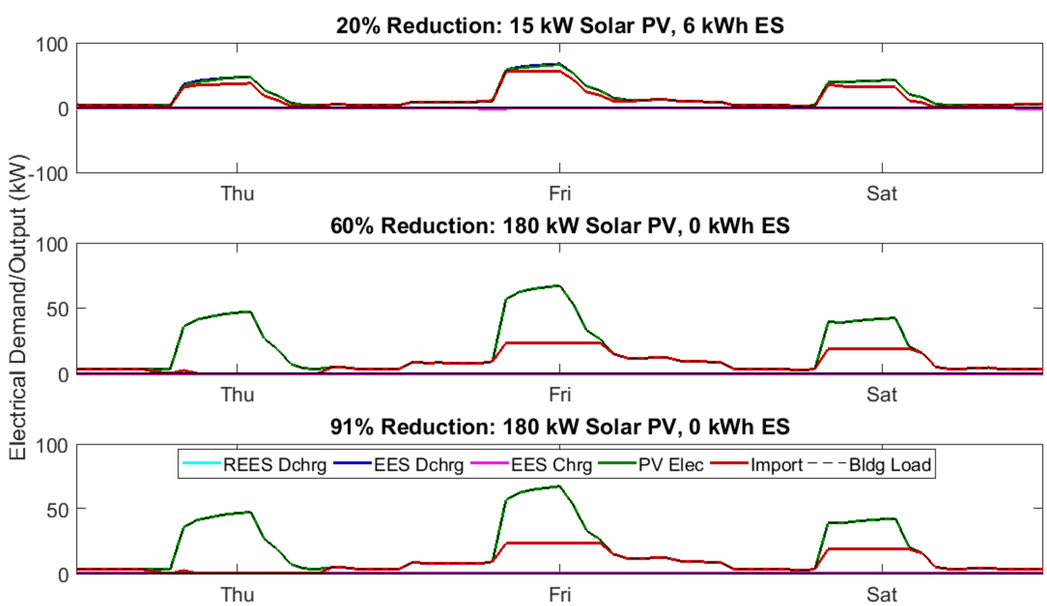
Source: University of California, Irvine

Figure 46: Solar Photovoltaic Operation at 17311 Koledo Ln (Residential) for Three Days when Net Electrical Use is Reduced by 20%, 60%, and 91%



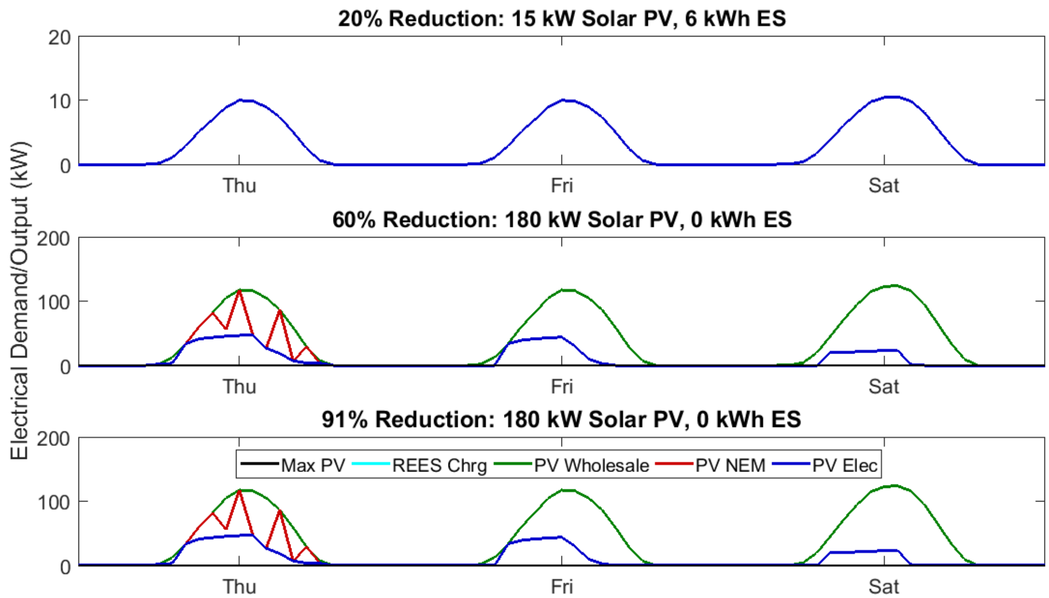
Source: University of California, Irvine

Figure 47: Distributed Energy Resource Operation at 17241 Oak Ln (Education) for Three Days when Net Electrical Use is Reduced by 20%, 60%, and 91%



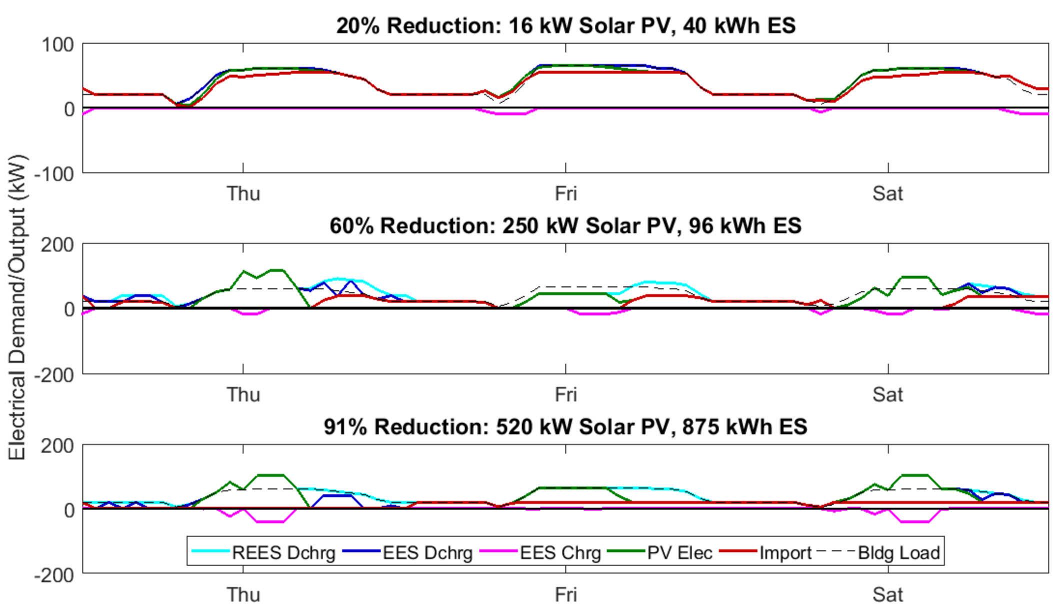
Source: University of California, Irvine

Figure 48: Solar Photovoltaic Operation at 17241 Oak Ln (Education) for Three Days when Net Electrical Use is Reduced by 20%, 60%, and 91%



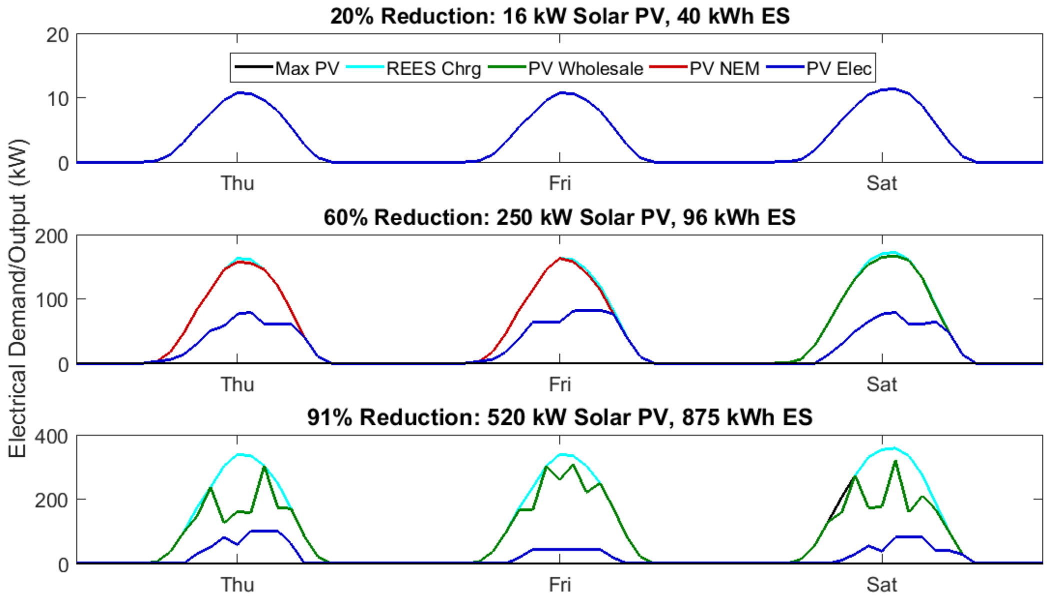
Source: University of California, Irvine

Figure 49: Distributed Energy Resource Operation at 7501 Slater Ave (Commercial and Industrial) for Three Days when Net Electrical Use is Reduced by 20%, 60%, and 91%



Source: University of California, Irvine

Figure 50: Solar Photovoltaic Operation at 7501 Slater Ave (Commercial and Industrial) for Three Days when Net Electrical Use is Reduced by 20%, 60%, and 91%



Source: University of California, Irvine

Table 31 shows the financial performance of the optimal DER systems.

Table 31: Financial performance of Optimal Distributed Energy Resource Systems at Different Levels of Net Electrical Energy Reductions

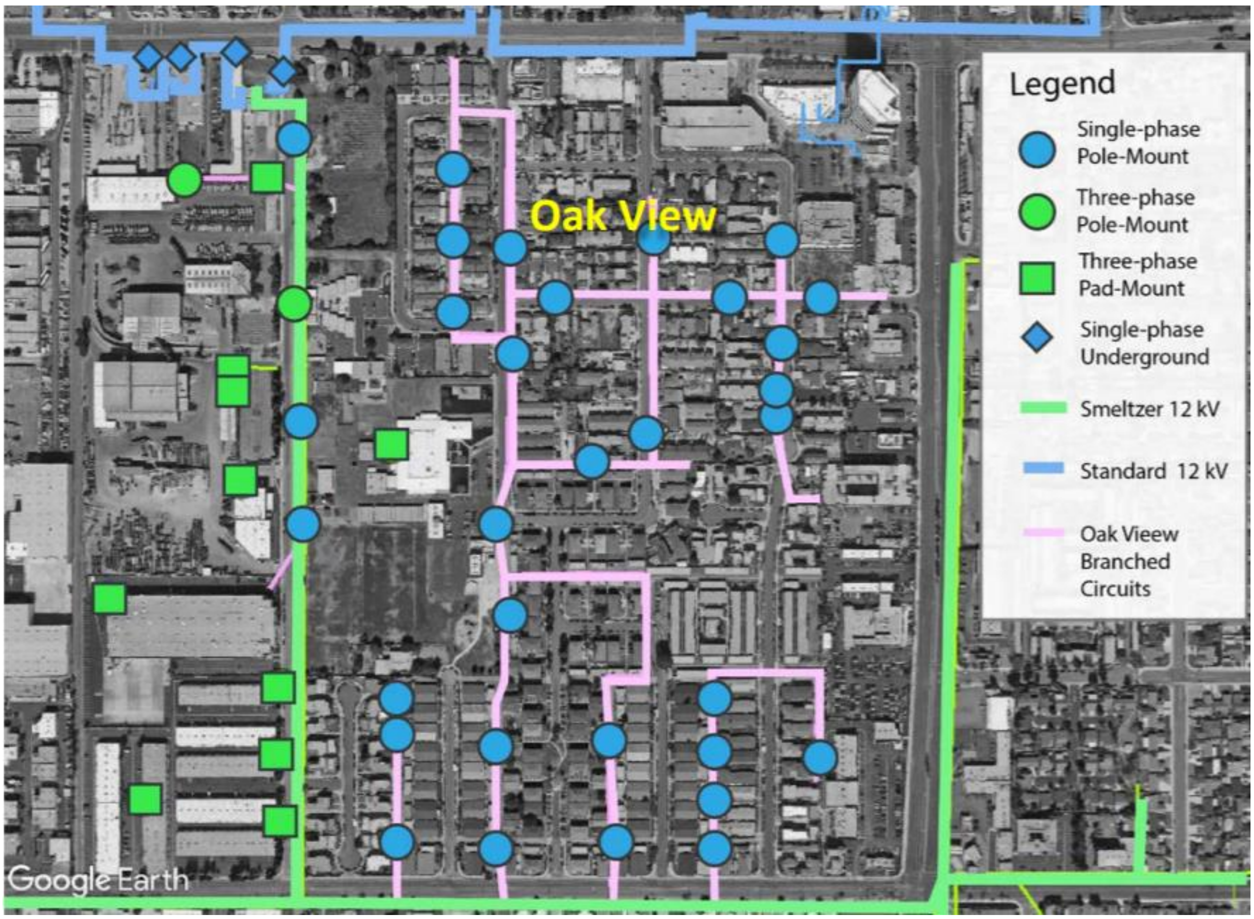
Net reduction from LED + Plug load (%)	20	40	60	80	85	87.5	90	91
Simple Payback (Years)	5.5	7.7	9.3	13.8	13.0	13.7	14.4	15.0
$/net kWh Saved	-0.065	0.029	0.069	0.170	0.150	0.163	0.176	0.184
Simple Payback CARE rates (Years)	14.2	14.8	16.1	20.6	19.2	19.8	20.8	21.5
$/net kWh Saved CARE rates	0.132	0.138	0.148	0.227	0.205	0.214	0.224	0.231

Source: University of California, Irvine

According to the results, the only system that experiences a simple payback faster than 10 years is when all residential customers are on standard rates and net electrical energy is reduced by 20 percent, 40 percent, and 60 percent. All other scenarios take longer than ten years to achieve simple payback. Since the goal of the optimization is to minimize cost subject to a constraint enforcing a reduction in net electrical energy use, an important criteria to consider is the cost per kWh or net electrical energy reduction. This value is also shown in Table 31. Note that the only scenario with a negative value (the AEC developer experiences a financial benefit for reducing net electrical energy use) is under standard rates with a 20 percent reduction. Regardless or number of residents on CARE rates, the cost to reduce net electrical energy use increases as the net energy demand decreases. This increase can be related to the need to purchase energy storage to support solar PV production.

In addition to implementing the proposed solar PV and EES system, an extensive electrical monitoring system would also need to be installed. The proposed locations for the monitoring equipment is at each individual transformer located in the Oak View community, as shown in Figure 51. This system would allow for the implementation of advanced control strategies, provide information for the development of a community energy use dashboard, and would allow for continuous benchmarking of the community to occur.

Figure 51: Location of Transformers in Oak View Community



Source: University of California, Irvine

Renewable Fuel Potential

This section uses the four solar PV scenarios developed for this work. The first scenario is presented later in the chapter, while the other three are presented in Appendix D. It was also assumed that higher efficiency panels were available under the maximum solar PV scenario, allowing for zero net electrical energy to be achieved. This work explored using excess solar to produce renewable fuel.

For each of the four PV size scenarios, two net solar electricity cases were calculated: a “copper plate” case where a lossless grid can transport electricity throughout the entire community to meet demand, and an “insulated sector” case where a lossless grid can transport electricity only throughout the sector in which it is produced to meet demand and exports excess to the local grid. The total community net solar production for the “copper Plate” and “insulated sector” cases for each of the solar PV scenarios are displayed in Table 32. The sector-resolved net solar production and unmet load for the "insulated sector" case of all four solar PV scenarios is shown in Table 33. See Appendix B for information about how values in Table 32 and Table 33 were calculated.

For the “copper plate” case, the maximum scenario corresponds to the largest net solar production, 11,620 MWh, and the smallest unmet load, 8,630 MWh. The other scenarios have net solar production values 6 - 61 times smaller than that of the maximum scenario. However, the total community load unmet by PV electricity production of the other scenarios is only 1.2 – 1.5) times larger than that of the maximum scenario.

The “insulated sector” case shows the same trends between scenarios. In this case, the maximum scenario again corresponds to the largest net solar production, 12,010 MWh, and the smallest unmet load, 8,690 MWh. The other scenarios have net solar production values 5 - 22 times smaller than that of the maximum scenario. The total community load unmet by PV electricity production of the other scenarios is the same as for the “copper plate” case. This suggests that the majority of solar PV added for the Maximum scenario compared to each of the other scenarios in “copper plate” and “isolated sector” cases is not being used to meet daytime demand.

Table 32: Total Community Net Solar Production for "Copper Plate" and "Insulated Sector" Cases for each of the Solar Photovoltaic Scenarios

	"Copper Plate"		"Insulated Sector"	
Scenario	Net Solar Production (MWh)	Unmet Load (MWh)	Net Solar Production (MWh)	Unmet Load (MWh)
Maximum	11,620	8,300	12,010	8,690
Grid Const.	1,940	9,990	2,350	10,410
Carport	190	12,300	540	12,650
SCE	1,450	10,300	2,070	10,920

Source: University of California, Irvine

The sector-resolved net solar production and unmet load for the "insulated sector" case of all four solar PV scenarios is shown in Table 33. The maximum solar PV scenario produced 6,200; 1,660; and 4,150 MWh in the residential, school commercial, and commercial and industrial sectors, respectively. The largest source of excess solar electricity in this scenario came from PV panels in the residential sector. Grid constraints applied in the grid constraint scenario reduce the amount of PV installed as compared to that in the maximum scenario and so decreases the Residential net solar production from 6,200 MWh to 1,000 MWh. In both the carport and SCE scenarios, solar electricity production in the residential sector does not meet the residential sector demand, and so zero MWh of net solar electricity production are generated.

Table 33: Sector-Resolved Annual Net Solar Production (a) and Unmet Load (b) for "Insulated Sector" Case of All Four Solar Photovoltaic Scenarios

(a)

Scenario	Net Solar Production (MWh)			
	Residential	School Commercial	C&I	Total Community
Maximum	6,200	1,660	4,150	12,010
Grid Const.	1,000	630	720	2,350
Carport	0	290	240	540
SCE	0	290	1,770	2,070

(b)

Scenario	Unmet Load (MWh)			
	Residential	School Commercial	C&I	Total Community
Maximum	2,770	120	5,810	8,690
Grid Const.	3,190	150	7,070	10,410
Carport	4,330	210	8,120	12,650
SCE	4,330	210	6,390	10,920

Source: University of California, Irvine

The case with maximum net solar production (max. NSP) is the maximum scenario "insulated sector" case producing 12,010 MWh of excess solar electricity. The case with minimum net solar production (min. NSP) is the carport scenario "copper-plate" case producing 190 MWh. These two cases will be analyzed further in following sections. Using these scenarios, the pathways described in the Renewable Fuel Production section of Chapter 4 were explored.

Path 1 Results

Path 1 describes natural gas pipeline injection of hydrogen fuel via electrolysis from excess solar PV electricity. In this path, electrolysis generates 29,500 MMBtu (86 million scf) in the maximum scenario "insulated sector" case and 469 MMBtu (1.4 million scf) for the carport scenario "copper plate" case from excess solar electricity.

Path 2 Results

In path 2, methane fuel is produced via electrolysis and methanation and via fuel from anaerobic digestion. This methane fuel is injected into the natural gas pipeline. For both the maximum scenario "insulated sector" case and the carport scenario "copper plate" case, path 2 produces 1,910 MMBtu of methane fuel via anaerobic digestion as this process is not affected by the magnitude of solar electricity production in the community. The methane fuel produced in the maximum scenario “insulated sector” case via electrolysis and methanation, 19,500 MMBtu, is nearly 63 times larger than that produced in the carport scenario “copper plate” case, 310 MMBtu. The total methane produced in the maximum scenario “insulated sector” case is 21,400 MMBtu (570,000 scf), and the total methane produced in the carport scenario “copper plate” case is 2,220 MMBtu (59,100 scf).

Path 3 Results

Path 3 includes only the injection of methane fuel produced via anaerobic digestion into the natural gas pipeline. As methane fuel production via anaerobic digestion is not dependent on the magnitude of solar PV electricity production, methane production in all cases is 1,910 MMBtu (50,800 scf).

Path 4 Results

Path 4 describes electricity production by SOFC running on methane fuel produced via electrolysis and methanation and via anaerobic digestion. Again, both the maximum scenario “insulated sector” case and the carport scenario “copper plate” case, produce 1,910 MMBtu of methane fuel via anaerobic digestion annually. This amount of methane fuel can sustain an SOFC operating at a steady power output of 0.038 MW (38 KW) for one year. The methane produced via electrolysis and methanation from excess solar electricity is over 10 times larger than that produced via anaerobic digestion for the maximum scenario “insulated sector” case. This amount of methane fuel can sustain an SOFC operating at a steady power output of 0.392 MW (392 KW) for one year. Combining both methane production pathways for this case could sustain an SOFC operating at a steady power output of 0.430 MW (430 KW) for one year.

The methane produced via electrolysis and methanation from excess solar electricity is over 6 times smaller than that produced via anaerobic digestion for the carport scenario “copper plate” case. This amount of methane fuel can sustain an SOFC operating at a steady power output of 0.006 MW (6 KW) for one year. Combining both methane production pathways for this case could sustain an SOFC operating at a steady power output of 0.045 MW (45 KW) for one year, almost 10 times less electricity production that in the maximum scenario “insulated sector” case.

Path 5 Results

Table 34 shows the energy content of methane produced via anaerobic digestion and hydrogen produced via electrolysis and the size SOFC that these fuel quantities could support separately and as a mixture for both scenario cases analyzed. In the maximum scenario “insulated sector” case, hydrogen fuel production via electrolysis is much greater than methane production via anaerobic digestion resulting in SOFC steady-state power outputs of 0.038 MW and 0.593 MW, respectively. A fuel mixture in the maximum scenario “insulated sector” case could support a 0.631 MW SOFC. In the carport scenario “copper plate” case, hydrogen fuel production via electrolysis is much less than methane production via anaerobic digestion resulting in SOFC steady-state power outputs of 0.009 MW and 0.038 MW, respectively. A fuel mixture in this scenario's case could support a 0.048 MW SOFC.

Table 34: Electrical Power Produced Annually in Path 5 Using a 60% Electrically Efficient Solid Oxide Fuel Cell Running on Mixture of Methane Fuel from Anaerobic Digestion and Hydrogen Fuel from Electrolysis

	Steady State SOFC Power Output, 60% electrical efficiency (MW)		
	CH_4 via AD	**H_2 via EC**	**Total**
Maximum Scenario "Insulated Sector" Case	0.038	0.593	0.631
Carport Scenario "Copper Plate" Case	0.038	0.009	0.048

Source: University of California, Irvine

Path 6 Results

Path 6 describes electricity production by a 60 percent electrically efficient SOFC running on methane fuel produced via anaerobic digestion. Again, for the maximum scenario "insulated sector" case and the carport scenario "copper plate" case, path 4 produces the same volume of methane fuel via anaerobic digestion annually as this process is not affected by the magnitude of solar electricity production in the community. This amount of methane fuel can sustain an SOFC operating at a steady power output of 0.038 MW (38 KW) for one year.

In the maximum scenario "insulated sector" case the net community demand after solar PV electricity generation is 8,693 MWh. If this load were distributed equally during one year it could be met by a steady-state SOFC with a 0.99 MW power output. Table 35 shows the percent net community demand met by each of the paths producing electricity via SOFC from (a) organic municipal solid waste (OMSW) produced by Oak View residents only and (b) from the total amount of OMSW processed at Republic Services.

In the maximum scenario "insulated sector" case, the largest percentage of community electrical demand met, 63.7 percent, was produced by Path 5. Hydrogen fuel produced via electrolysis contributes almost 94 percent of the fuel energy used by the 0.631 MW SOFC. Methane produced via anaerobic digestion provides the remaining 6 percent. Cases that include the total OMSW processed by Republic Services presently and at expanded capacity estimates exceed the community's net electrical demand by 380-529 percent.

When only community-produced OMSW is considered, electrolysis and methanation contribute fuel for 91-94 percent of all electrical energy produced in the cases shown in Table 36. When all OMSW processed at the transfer station is considered, electrolysis and methanation contribute fuel for 12 percent of all electrical energy produced in the cases shown.

The decreased renewable PV electricity generation in the carport scenario "copper plate" case produces a net community demand after solar electricity generation of 12,302 MWh, about 150 percent of that for the maximum scenario "insulated sector" case. If this net load were distributed equally over the course of one year it could be met by a steady-state SOFC with a 1.4 MW power output.

Table 35: Percent Total Community Net Demand of the Maximum Scenario "Insulated Sector"

(a) **Oak View Electrical End Use Paths**

Path Number	Energy (MWh)	SOFC (MW)	% Community Net Electrical Demand Met
4 (AD, EC, and MT to SOFC)	3,770	0.430	43.4%
5 (AD and EC to SOFC)	5,530	0.631	63.7%
6 (AD to SOFC)	336	0.038	3.9%

(b) **Total Republic Biogas Current Capacity Electrical End Use Paths**

Path Number	Energy (MWh)	SOFC (MW)	% Community Net Electrical Demand Met
4 (AD, EC, and MT to SOFC)	41,700	4.76	480%
5 (AD and EC to SOFC)	43,500	4.96	500%
6 (AD to SOFC)	38,300	4.37	440%

Case Met by Steady-State Solid Oxide Fuel Cell Maximum Electricity Generation Supported by Fuel Produced in Paths 4-6 for Two Anaerobic Digestion Feedstock Cases: (a) Only Oak View Resident-Produced OMSW and (b) Total Amount of OMSW Currently Processed at Republic Services

Source: University of California, Irvine

Table 36: Percent Total Community Net Demand of Carport Scenario "Copper Plate"

(a) **Oak View Electrical End Use Paths**

Path Number	Energy (MWh)	SOFC (MW)	% Community Net Electrical Demand Met
4 (AD, EC, and MT to SOFC)	390	0.045	3.2%
5 (AD and EC to SOFC)	418	0.048	3.4%
6 (AD to SOFC)	336	0.038	2.7%

(b) **Total Republic Biogas Current Capacity Electrical End Use Paths**

Path Number	Energy (MWh)	SOFC (MW)	% Community Net Electrical Demand Met
4 (AD, EC, and MT to SOFC)	38,300	4.37	312%
5 (AD and EC to SOFC)	38,400	4.38	312%
6 (AD to SOFC)	38,300	4.37	311%

Case Met by Steady-State Solid Oxide Fuel Cell Maximum Electricity Generation Supported by Fuel Produced in Paths 4-6 for Two Anaerobic Digestion Feedstock Cases: (a) Only Oak View Resident-Produced OMSW and (b) Total Amount of OMSW Currently Processed at Republic Services

Source: University of California, Irvine

In the carport scenario "copper plate" case, the largest percentage of community electrical demand met by sustainably produced fuel, 3.4 percent, was produced by Path 5. Hydrogen fuel produced via electrolysis contributes only 21 percent of the fuel energy used by the 0.48 MW SOFC. The remaining 79 percent comes from methane produced via anaerobic digestion. Cases that include the total OMSW processed by Republic Services presently and at expanded capacity estimates exceed the community's net electrical demand by 311-312 percent. The community electrical load in this case, with little solar PV, is larger than that of the previous case and so the percentage of community electrical demand met via anaerobic digestion is lower.

Using the Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool 2017, a module of the GREET 2016 software, produced by USDOE's Argonne National Laboratory, the team calculated the expected emissions for trucking the OMSW feedstock processed at the Republic transfer station in Huntington Beach to CR&R Environmental Services' anaerobic digester in Perris, California. The shortest path length between the facilities is 66.6 miles (133.2 miles roundtrip) [12].

Four types of heavy-duty vehicles were considered for the transport of 78,000 UST of OMSW, the total mass of OMSW processed in 2017 as shown in Table 37: class 7 single unit short-haul (SUSH), class 7 single unit long haul (SULH), class 8 combination short-haul (CSH), and class 8 combination long-haul (CLH). All trucks are assumed to be 2017 models.

Dividing the annual mass of OMSW processed by the maximum payload capacity of each vehicle and rounding up to the nearest whole number gives the number of roundtrips needed to transport all OMSW. The AFLEET tool input, number of vehicles, was calculated by dividing the number of roundtrips by the annual miles per vehicle listed in Table 37. Fractional numbers of vehicles are not rounded to the nearest whole to ensure that calculations are based on the minimum number of miles required to transport all OMSW and result in conservative estimates of criteria pollutant emissions and fuel consumption. The results of these calculations and the annual fuel consumption and operating emissions per vehicle fleet is shown in Table 37.

Both class 7 vehicle types have the same maximum payload and so both class 7 fleets travel 1,364,900 miles annually in 10,247 roundtrips between the Republic Services facility and the CR&R Services facility. Similarly, both class 8 vehicle types have the same maximum payload and so class 8 fleets travel 467,665 miles annually in 3,511 roundtrips between the Republic Services facility and the CR&R Services facility. The class 7 SUSH fleet is the largest requiring 82.7 vehicles to transport all OMSW. The class 8 CLH fleet is the smallest requiring only 2.8 vehicles to transport all OMSW. The class 8 CSH fleet consumes the least amount of fuel and produces the least amount of all criteria pollutants compared to all the other fleets analyzed.

The percent fuel energy consumed as diesel fuel during transportation compared to the fuel energy that could be produced from the OMSW via anaerobic digestion ranges from 3.8 percent for the class 8 CSH fleet to 12.6 percent for the class 7 SULH fleet.

Table 37: Properties of Vehicle Fleets Required to Transport OMSW for Four Heavy-Duty Vehicle Types

Truck Class		7		8	
Truck Description, 2017 Model		Single Unit Short-Haul	Single Unit Long-Haul	Combination Short-Haul	Combination Long-Haul
Total Vehicle Roundtrips Per Year		10,247	10,247	3,511	3,511
Total Annual Miles Travelled by Fleet		1,364,900	1,364,900	467,665	467,665
Number of Vehicles in Fleet		82.7	59.3	7.2	2.8
Annual Fleet Criteria Pollutant Emissions	**GHG (UST)**	2,622	2,952	899	926
	CO (lbs.)	1,862	1,634	570	1,053
	NO_X (lbs.)	2,702	2,449	1,337	2,666
	PM10 (lbs.)	45	45	28	37
	PM10 (TBW) (lbs.)	328	364	147	160
	PM2.5 (lbs.)	42	41	25	34
	PM2.5 (TBW) (lbs.)	42	48	19	21
	VOC (lbs.)	198	168	51	235
	VOC (Evap) (lbs.)	60	63	48	53
	SO_X (lbs.)	29	32	10	10
Fleet Annual Fuel Energy Consumption	**Fleet Fuel Consumption (GGE/year)**	212,787	239,809	72,992	75,257
	Energy content of Diesel Consumed (MMBtu)	24,279	27,363	8,329	8,587
	% CH_4 (via AD) Energy Consumed in Transport of OMSW	11.1%	12.6%	3.8%	3.9%

Source: University of California, Irvine

Note that Republic currently plans on pursuing the trucking option. Combined with the expense associated with local natural gas injection into the pipeline, the current cost of small electrolyzers, and the community's resistance against renewable natural gas production within the community, these options are not included in the final design.

Electric Car Share Potential

According to the car share developer that is exploring the potential of an electric car share service within the community, one vehicle should be adopted per 100 units of housing. According to this metric, approximately 18 vehicles should be adopted. However, parking is impacted in this community, and no property owner has expressed interest in supporting this aspect of the program.

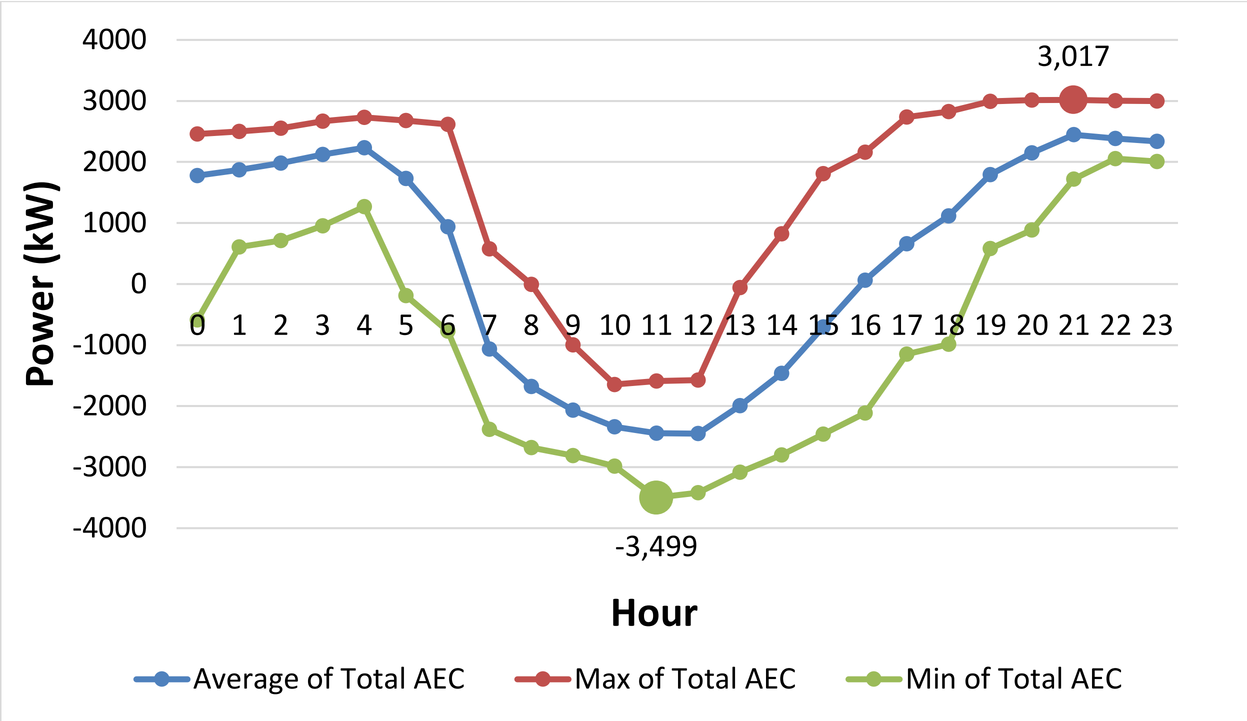
Technical Advanced Energy Community Feasibility

This section provides an impact study of a given PV and ESS optimal allocation (sizing and location) at the 12 kV Smeltzer and Standard circuits, part of the California Edison's Ocean View 66/12 kV substation. This analysis uses a comprehensive steady-state computer model developed in a commercial power flow software, namely ETAP. The model captures the Oak View community power system from the 66 kV medium-voltage distribution level down to the 120/240 V, for single phase services, or 480/277 V, for three-phase services. The scenario studied represents DER allocation to achieve Net Zero power demand for the Oak View AEC . The DER deployment to attain such goal was evaluated concerning the operational implications of their respective DER deployments. Aggregated transformer injection profiles were calculated by DERopt for the entire AEC during a representative one year interval. The results presented in this section examine the scenario where net electrical energy use is reduced by 91 percent. Reverse power flow, or electrical export, is highest under this scenario. AS a result, this scenario is most likely to cause a circuit overload or other critical grid fault.

Max Repeated Power Flow and Peak Load

Aggregated hourly transformer power injections calculated by DERopt are shown in Figure 52. The aggregated hourly power injections are the sum of all transformer contributions during the representative year simulated and represent the total power flows for the Oak View AEC. The PV generation and ESS charge and discharge is captured in these injections. The sign convention shows positive power as imported (load) and negative power as exported (generation). In this scenario, the hourly-averaged values are shown in the blue curve (average of total AEC). The hourly-maximum values are shown in the red curve (Max of Total AEC), and capture a peak demand of 3,017 kW, which happened at 21:00. The hourly-minimum aggregated AEC profile captures a maximum RPF of 3,499 kW, which occurred at 11 a.m.

Figure 52: Scenario 1 - Oak View Hourly-Averaged Transformer Injections (kW)



Source: University of California, Irvine

Transformer Power Injections and Power Ratings

After identifying when the maximum repeated power flow (RPF) event, the several individual transformer injections calculated by DERopt were identified and used as inputs to the ETAP model. These injections are shown in Table 38. Note that some of the transformer power ratings were increased from its original size. This assumption was made to guarantee that the transformer could accommodate the loads estimated by URBANopt, and that DERopt would produce a feasible solution. The required additional transformer capacity was 1,050 kW. The transformers which had upgraded ratings are shown in red in Table 38.

Thermal Loading

From the simulation results, thermal loading was assessed on all the transformer and circuits of the Oak View AEC. A load flow analysis identified marginal (above 95 percent and up to 100 percent of rated power/ampacity) and critical (above 100 percent of rated power /ampacity) overloads for the maximum RPF event of the transformer injections described earlier. Two critical thermal loading concerns were identified in two overhead 12 kV circuit branches near the head of the Smeltzer circuit. The rating of these branches was 165 A (3/0 AWG) and 141 A (2/0 AWG) and were operating at 172 A and 164 A, respectively, which represent critical overloads of 116 percent and 104 percent, respectively. Regarding transformers, no power rating was exceeded (above 100 percent).

Table 38: Scenario 1 – Net Ze0p - DERopt Transformer Injections and Updated Ratings

Transformer name	Injection (KW)	Transformer Updated Ratings (KVA)
'T1P-10'	-75.0	75
'T1P-11'	-57.5	57.5
'T1P-12'	-25.0	25
'T1P-13'	-55.0	55
'T1P-14'	-55.0	55
'T1P-15'	-70.0	70
'T1P-16'	-55.0	55
'T1P-17'	-30.0	30
'T1P-18'	-55.0	55
'T1P-19'	-50.0	50
'T1P-2'	-30.0	30
'T1P-20'	-50.0	50
'T1P-21'	-8.4	15
'T1P-22'	-20.0	20
'T1P-23'	-37.5	37.5
'T1P-24'	-85.0	85
'T1P-25'	-42.5	42.5
'T1P-26'	-125.0	125
'T1P-27'	-20.0	20
'T1P-28'	-25.0	25
'T1P-29'	0.0	25
'T1P-3'	-25.0	25
'T1P-30'	-35.4	75
'T1P-31'	-95.0	95
'T1P-32'	-55.0	55
'T1P-4'	-25.0	25
'T1P-5'	-25.0	25
'T1P-6'	-65.0	65
'T1P-6-Commercial'	-80.0	80
'T1P-7'	-65.0	65
'T1P-8'	-60.0	60
'T1P-9-Residential'	-100.0	100
'T3P-11.2'	-132.1	300
'T3P-2.1'	-68.7	75
'T3P-2.2'	-67.4	150
'T3P-2.3'	-150.0	150
'T3P-2.4'	-225.0	225
'T3P-3'	-788.8	1500
'T3P-4'	-62.4	75
'T3P-5.1-Commercial'	137.8	690
'T3P-5.1-Residential'	-33.3	100
'T3P-5.2'	-77.8	160
'T3P-5.3'	-80.0	350
'T3P-5.4'	-125.0	125
'T3P-5.5'	0.0	150
'T3P-8'	-75.0	75
'T3P-9'	-150.0	150

Source: University of California, Irvine

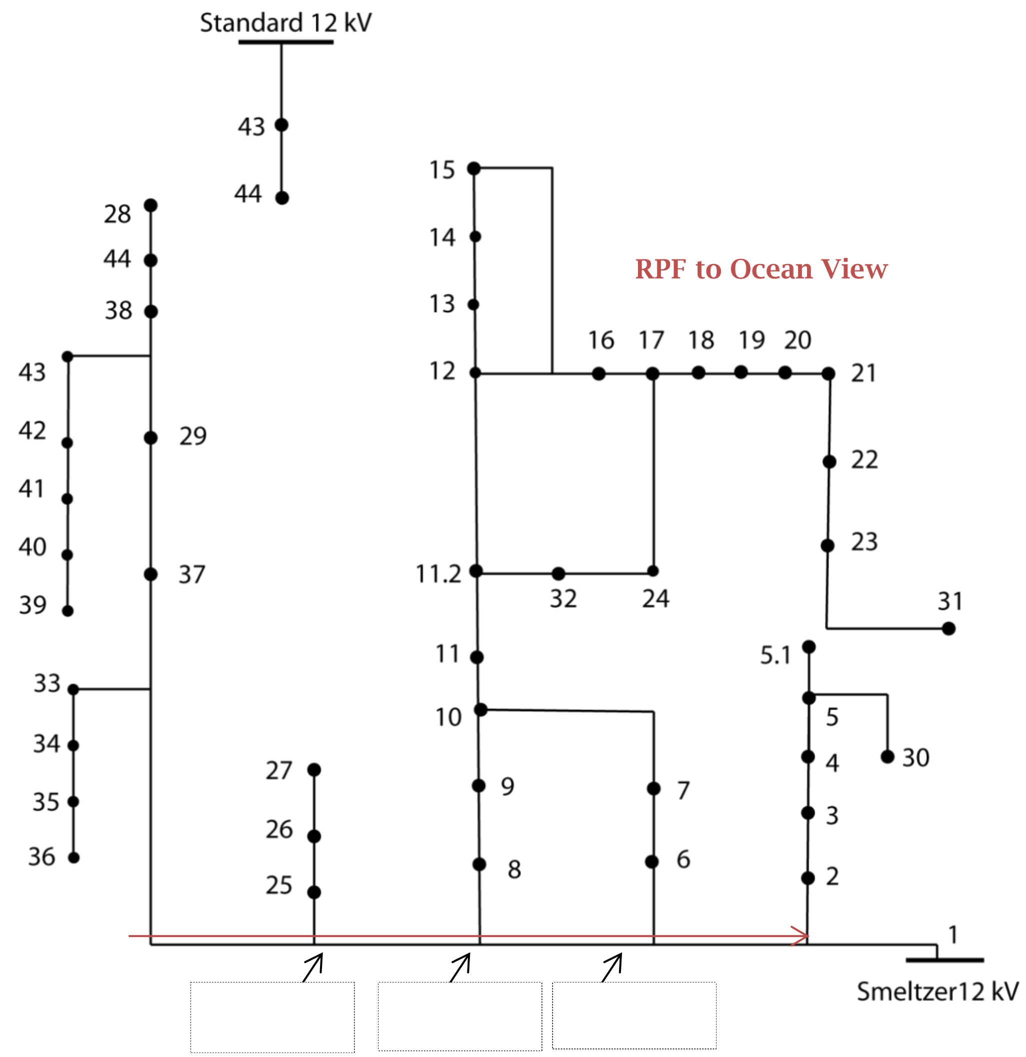
Table 39: Number of Critical and Marginal Overloads

Smetzer 1	Line	165	172 A (Phase B)	104%
Smeltzer 2	Line	141	164 A (Phase B)	116%
Smeltzer 3	Line	120 A	116 A(Phase B)	96.6%

Source: University of California, Irvine

Figure 53 illustrates the location of the overloaded circuits in the Oak View AEC power system. Note that through these branches, the sum of the individual RPF currents from all the community branches adds up to flow upstream, to the Ocean View substation.

Figure 53: Location of Overloaded Circuits



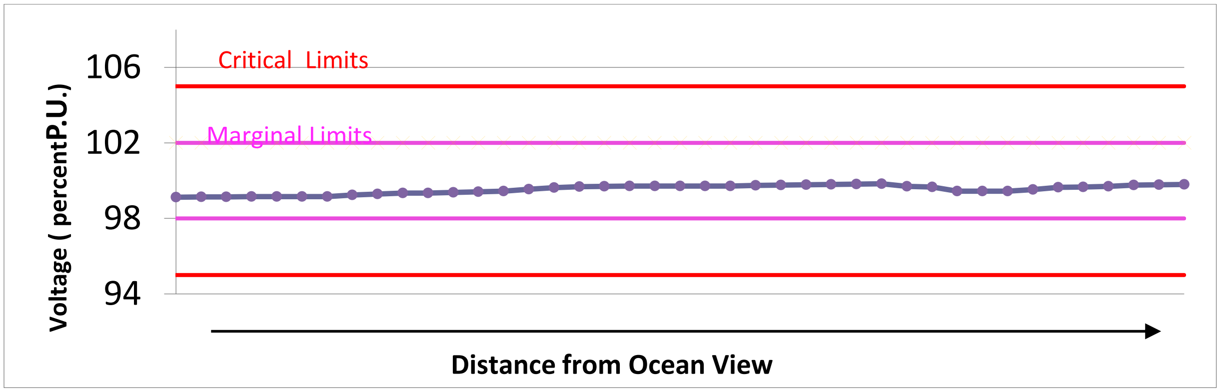
Source: University of California, Irvine

Steady-State Voltage

The addition of the optimized DER allocation calculated by DERopt for a net zero goal was studied to determine the impact on the steady-state voltage and the voltage profile of Smeltzer and Standard circuits. Figure 54 and Figure 55 plot the primary and secondary voltage profiles (voltage vs. distance from the substation) for both Smeltzer and Standard circuits. The maximum voltage for primary buses (12 kV) does not exceed 99.8 percent per unit. Therefore, no concerns regarding overvoltage on primary circuits were identified. In secondary circuits, one single bus registered a marginal over-voltage of 102.3 percent per unit. This bus connects to the secondary of T3P-5.3, which feeds Republic Environmental Services' loads. The fact that this bus is located at the end of the Smeltzer circuit (where the total impedance is higher) and that high PV injections surround it contribute to this marginal over-voltage event. Nonetheless, no critical overvoltages (above 105 percent per unit) were identified.

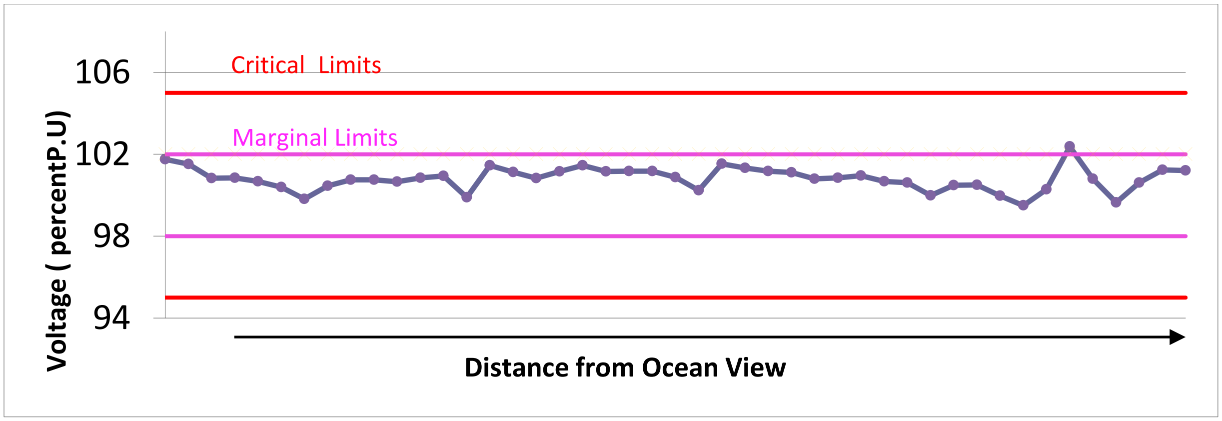
These results reinforce the finding of previous analysis that limiting nodal power injections by the local transformer's rating is an effective way of eliminating most over-voltage challenges caused by PV RPF.

Figure 54: Steady-State Voltage Profile - Primary Buses



Source: University of California, Irvine

Figure 55: Steady-State Voltage Profiles - Secondary Buses



Source: University of California, Irvine

Financial Model

The combined capital cost of the ECMs and DER technologies required to reduce net electrical use by approximately 94 percent exceeds $40 million. Considering the proposed budget for the implementation phase of this project, the AEC design must be scaled down to select partners. For the implementation phase, the initial set of community partners that will be included in the implementation are the same partners as those listen in the beginning of this section. The decision to focus on key partners versus the whole community is based on the need to strategically select locations and partners to ensure AEC implementation success. However, the AEC design in general will not change. A concept created through this work is to think of the local utility grid as a scarce resource. Since an AEC developer is unlikely to want to upgrade the existing local utility infrastructure (such a decision may require the purchase of the entire section of circuit infrastructure from the local utility), the ability to send electricity back to through local transformers and wires must be managed when deciding where to put solar PV and EES, and these technologies must be operated to ensure feasible operation. Based on this, the ability of the local utility to absorb excess energy is diminished as community members export more and more, resulting in a scarce resource. With this understanding, the Oak View AEC will be designed based on the results from this work to ensure that future renewable and clean technologies can be rolled out in a way that optimizes the benefits for the community. This shift in focus away from individual resource to community wide resource optimization is critical to establishing and maintaining community value.

The HB AEC design elements are:

- Community-scale LED interior and exterior lighting upgrades.
- Residential appliance replacements and plug-load controls.
- Commercial plug and process load (PPL) controls.
- Canopy and rooftop solar PV installations.
- Battery installation for electricity storage.
- Advanced community-level electrical metering and energy dashboarding.

As part of the technical design and financial and business model, residential insulation upgrades and residential water reduction technologies may be included in the implementation phase, contingent on funding. These elements were not included in the final financial and business model.

The total installed cost of the community-wide ECMs is estimated to be $3.3 million, with a majority allocated towards the residential plug-load controls ($2.6 million); the simple payback of the ECMs is between 2.1 under standard SCE rates and 2.4 years, under SCE CARE rates.

The remaining $11.7 million of the $15 million project budget is allocated to DER (solar PV and battery installations) and community-level energy metering and dashboarding. With the budget of constraint of $11.7 million, 3.2 MW of solar with 1.3 MWh of battery storage is employed in the community. Table 40 shows the solar and battery storage allocation; a map defining the different areas is shown in

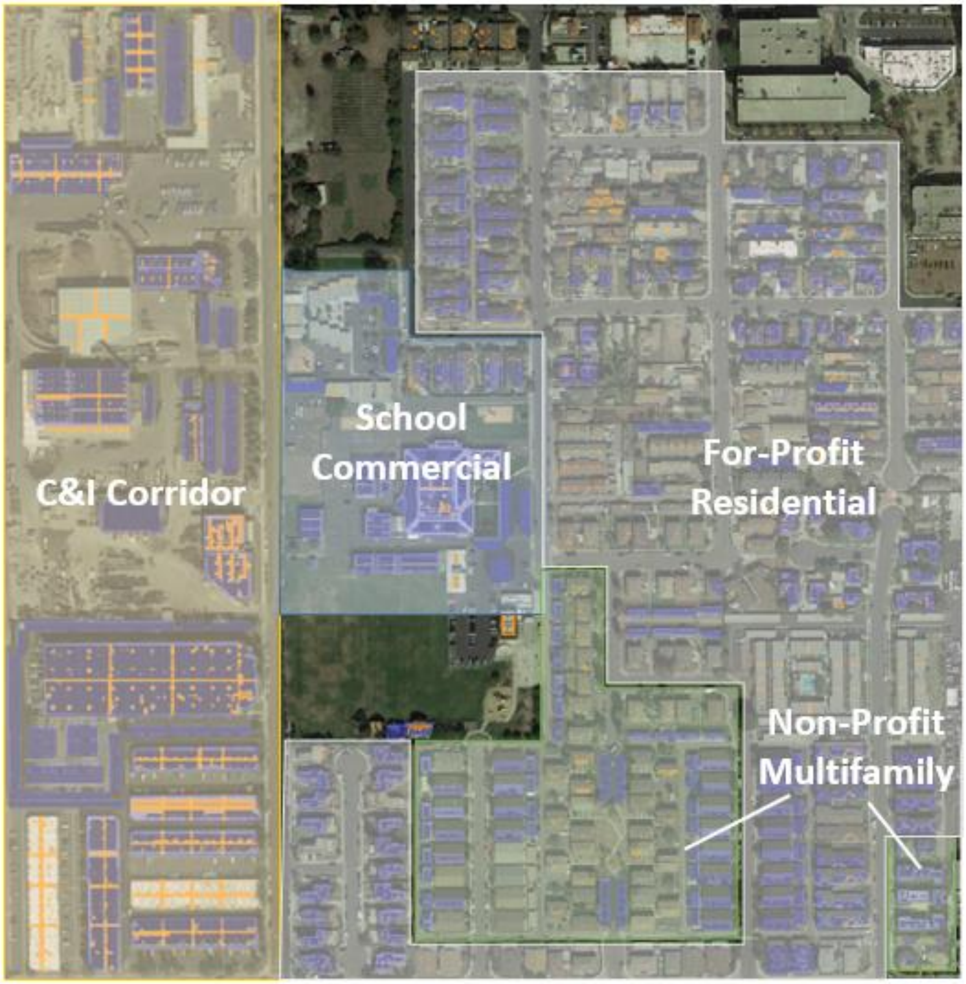
Figure 56.

Table 40: Solar Photovoltaic and Battery Installation Breakdown by Area

	Solar Capacity (kW)					
Installation Area	**Rooftop**	**Canopy**	**Total**	**Solar Distribution (%)**	**Battery Storage (kWh)**	**Battery Distribution (%)**
Non-Profit Multifamily	120	0	120	4%	0	0%
For-Profit Residential	240	0	240	8%	0	0%
School Commercial (School and Community Buildings)	670	0	670	21%	40	3%
C&I Corridor	2,040	100	2,140	68%	1,240	97%
Community	**3,070**	**100**	**3,170**	**100%**	**1,280**	**100%**

Source: University of California, Irvine

Figure 56: Map of Advanced Energy Community Implementation Area



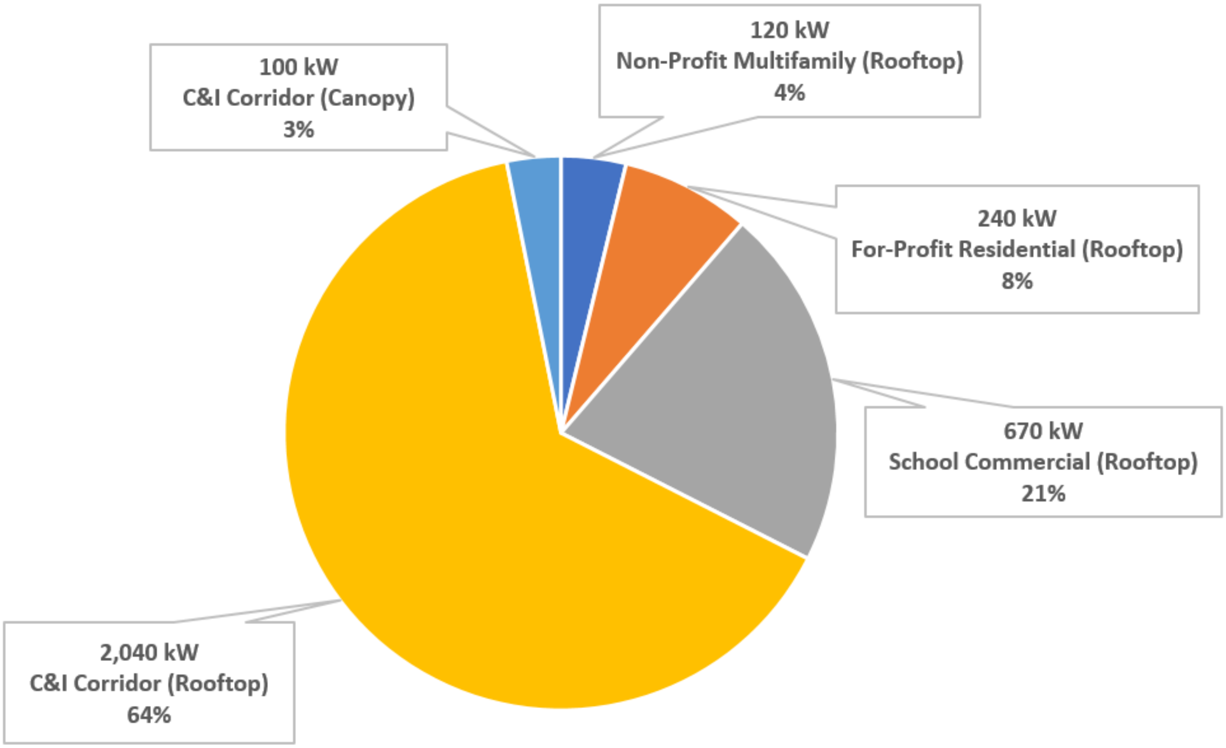
Source: University of California, Irvine

The solar design considers fire code regulated setbacks, limitations based on roof structural capacity and grid power constraints.

The solar PV design includes both rooftop and canopy solar installations. The total size, type and capacity for each area is listed in

Figure 57. The total amount of solar capacity deployed in the Oak View community is 3,070 kW.

Figure 57: Solar Capacity Breakdown by Area



Source: Altura Associates

To maximize the effectiveness of the solar PV installations, distributed battery installations are also installed at all solar sites. The battery installations offset the peak solar production during the middle of the day and work to level electric load throughout the community. Table 41 shows the PV and battery capacity installed under the community design.

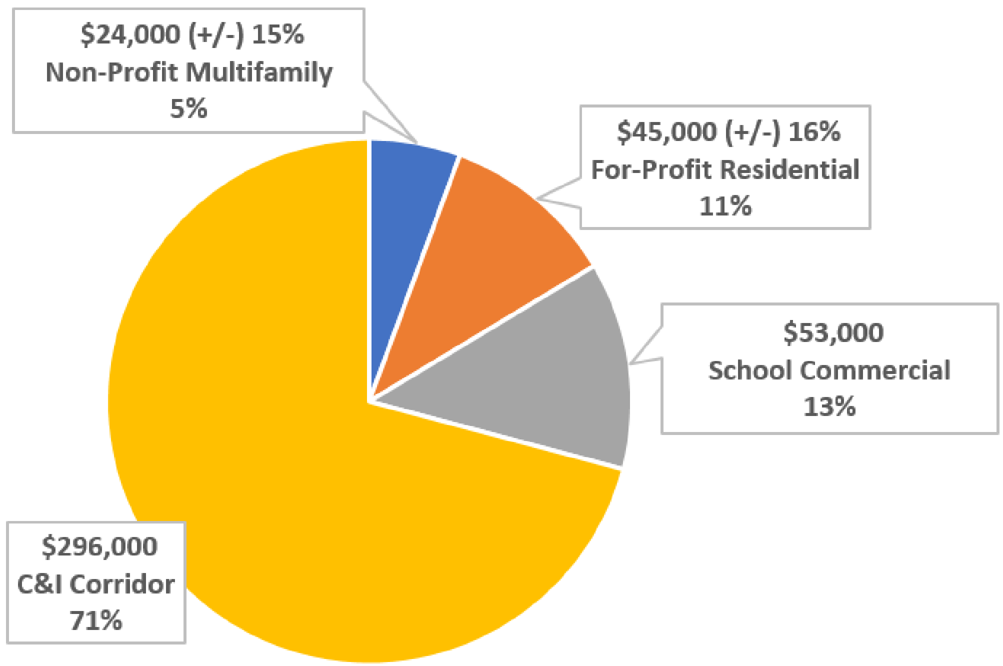
The energy cost savings estimated by DERopt for placing solar and battery technologies within the community is $471,000, regardless of CARE rates. The full energy cost profile can be found in Figure 58Error! Reference source not found.. A percent is listed after the energy cost reductions for the non-profit housing area; this shows the spread of savings due to CARE rates.

Table 41: Solar and Battery Capacity by Area

Installation Area	Solar Capacity (kW) Rooftop	Canopy	Total	Battery Storage (kWh)
Non-Profit Multifamily	120	0	120	0
For-Profit Residential	240	0	240	0
School Commercial	670	0	670	40
C&I Corridor	2,040	100	2,140	1,240
Community	**3,070**	**100**	**3,170**	**1,280**

Source: University of California, Irvine

Figure 58: Solar Photovoltaic and Battery Energy Cost Reductions by Area



Source: Altura Associates

A breakdown of energy savings, installation costs and energy cost savings allocated by sector is displayed in Table 42. Residential data is related to installing solar and battery in the non-profit housing sector. Commercial and industrial data is broken down by building type; commercial consists of school commercial (school and community buildings) and small commercial building and industrial is dominated by Republic and Zodiac. Industrial DER installations accounts for the majority of energy savings realized from applying DER technologies.

Table 42: Solar Photovoltaic and Battery Installation Energy, Cost, and Savings Profile by Sector

Sector	Solar Cost ($)	Battery Cost ($)	Total DER Cost ($)	Energy Savings (MWh)	Reduction from Electricity Baseline	Energy Cost Savings ($/year)	Simple Payback (years)
Residential	$1,127,000	$0	$1,127,000	540	-2.9%	$24,000 (+/-) 15%	48.0 (+/-) 2%
Commercial	$4,600,000	$395,000	$4,995,000	2,000	-10.9%	$210,000	23.8
Industrial	$4,940,000	$500,000	$5,440,000	3,200	-17.5%	$143,000	38.0
Community	**$10,667,000**	**$895,000**	**$11,562,000**	**5,740**	**-31.3%**	**$353,000**	**32.8**

Source: University of California, Irvine

Using the revised solar PV systems across the community, the modified system can be feasibly implemented using the implementation phase funding. The reduced AEC design is able to realize significant reductions in net electrical energy use while remaining within the projected budget.

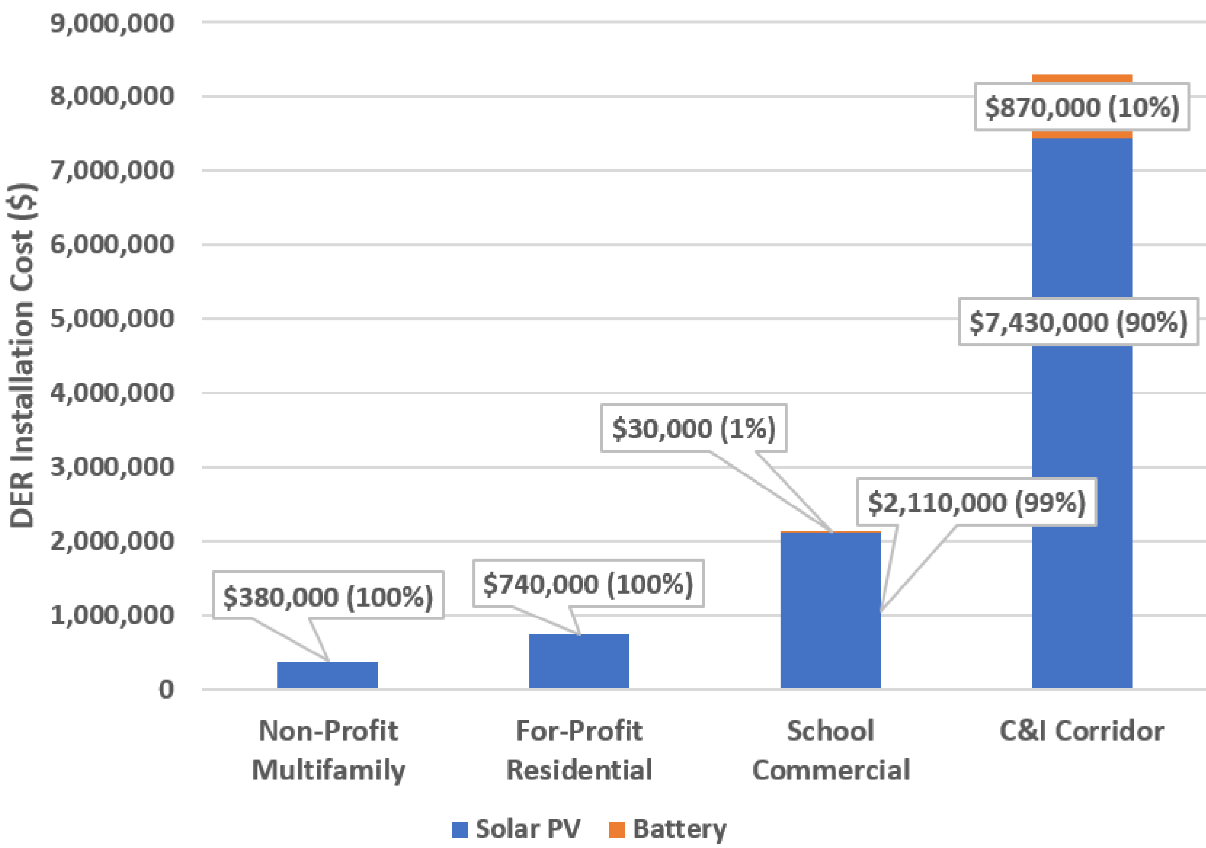
Since the design area consists of numerous low income households, it is expected that the residents will qualify for certain EE and solar PV incentives that have income qualification requirements. In particular, CAPOC has been targeted as an important partner for the ECM installation portion of the project. By targeting these ECM incentives for implementation across a large portion of the community, the team will gain access to low cost ECM. These economies of scale can be used to provide the educational and C&I sector with low cost ECMs.

The total cost of applying ECMs to the community is $3.3 million, accounting for 22 percent of total project cost. The total CEC funded amount for ECM applications is $700,000, or 21 percent of total ECM spending. The cost-share provided by the various partners is $2.6 million (79 percent). The cost-share contributions are listed below:

- CAPOC: $2.4 million (73 percent)
- CEC: $700,000 (21 percent)
- Property Owners: $70,000 (2 percent)
- Rexel: $60,000 (2 percent)
- Housing Authorities: $50,000 (2 percent)

The total cost of installing DER technologies is $11.6 million. Under the current design, solar PV systems account for $10.7 million (92 percent) of the final cost and battery installations make up $900,000 (8 percent). Further details around solar and battery costs for each area can be found in Figure 59 and Table 43.

Figure 59: Solar Photovoltaic and Battery Installation Energy Cost Breakdown by Area



Source: Altura Associates

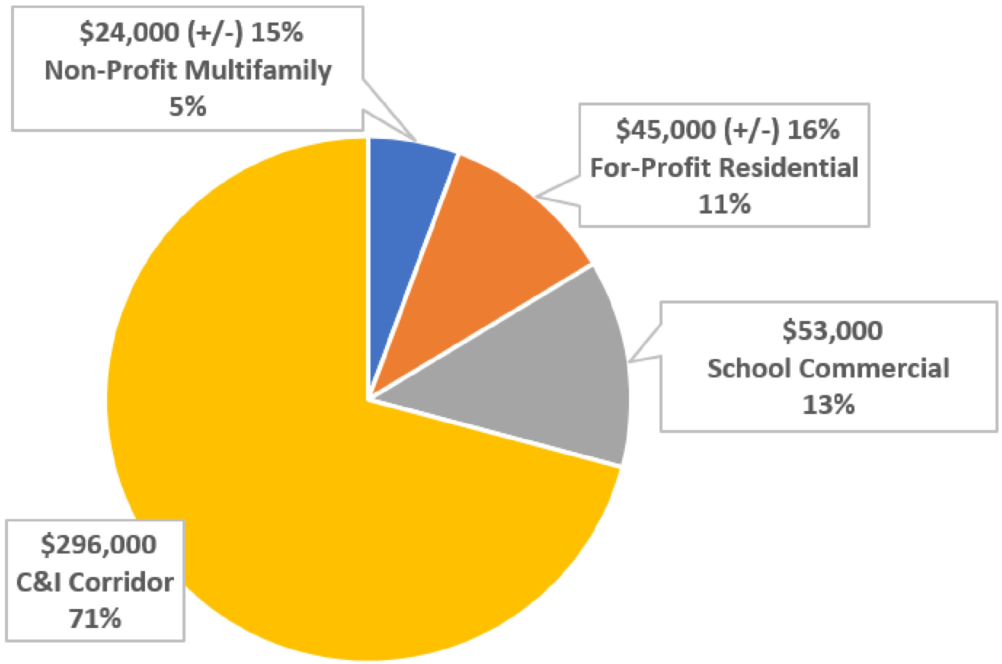
Table 43: Solar Photovoltaic and Battery Installation Cost Breakdown by Area and Installation Type

Installation Area	Solar Cost - Rooftop ($)	Solar Cost - Canopy ($)	Total Solar Cost ($)	Battery Cost ($)	Project Cost ($)	Allocations of Total Cost (%)
Non-Profit Multifamily	$380,000	$0	$380,000	$0	$380,000	3%
For-Profit Residential	$740,000	$0	$740,000	$0	$740,000	6%
School Commercial	$2,110,000	$0	$2,110,000	$30,000	$2,140,000	19%
C&I Corridor	$6,870,000	$560,000	$7,430,000	$870,000	$8,300,000	72%
Community	**$10,100,000**	**$560,000**	**$10,660,000**	**$900,000**	**$11,560,000**	**100%**

Source: University of California, Irvine

The energy cost savings estimated by DERopt for placing solar and battery technologies within the community is $471,000, regardless of CARE rates. The full energy cost profile can be found in Figure 58. A percent is listed after the energy cost reductions for the non-profit housing area; this shows the spread of savings due to CARE rates.

Figure 60: Solar Photovoltaic and Battery Energy Cost Reductions by Area



Source: Altura Associates

A breakdown of energy savings, installation costs and energy cost savings allocated by sector is displayed below. Residential data is related to installing solar and battery in the non-profit housing sector. Commercial and industrial data is broken down by building type; commercial consists of school commercial (school and community buildings) and small commercial building and industrial is dominated by Republic and Zodiac. Industrial DER installations accounts for the majority of energy savings realized from applying DER technologies.

Table 44: Solar Photovoltaic and Battery Installation Energy, Cost and Savings Profile by Sector

Sector	Solar Cost ($)	Battery Cost ($)	Total DER Cost ($)	Energy Savings (MWh)	Reduction from Electricity Baseline	Energy Cost Savings ($/year)	Simple Payback (years)
Residential	$1,127,000	$0	$1,127,000	540	-2.9%	$24,000 (+/-) 15%	48.0 (+/-) 2%
Commercial	$4,600,000	$395,000	$4,995,000	2,000	-10.9%	$210,000	23.8
Industrial	$4,940,000	$500,000	$5,440,000	3,200	-17.5%	$143,000	38.0
Community	**$10,667,000**	**$895,000**	**$11,562,000**	**5,740**	**-31.3%**	**$353,000**	**32.8**

Source: University of California, Irvine

As with ECM application, internal and external partners are critical to success in procuring DER technologies in the community. The major external partners for DER technologies are Tesla and GRID Alternatives. Tesla brings extensive experience in the solar and battery industry. GRID Alternatives has strong experience in administering solar programs for low-income residents in many areas of California.

GRID Alternatives specializes in PV installations for low-income properties. Leveraging funding from the Solar on Multifamily Affordable Housing (SOMAH) program, GRID Alternatives would be able to provide solar installations at low-income multifamily properties, covering 80-100 percent of project cost. Properties where owners have incomes less than or equal to 80 percent of the area median income and non-profit housing developments are eligible for this funding. Projects are incentivized to allocate the majority of the produced solar energy towards tenant energy bills through rebates based on load designation. Through the virtual net energy metering (VNEM) allowance in the SOMAH bills, energy savings would be able to be allocated to the low-income tenants, in many cases, resulting in energy cost reductions on the bills of the residents.

Under SOMAH legislation, $100 million is provided for each of the next 10 years, funded by the state's cap-and-trade program. GRID Alternatives would be the project partner and would apply for funding through the state program. The program funding structure is still being developed by the state, however, the program is estimated to be ready in the first quarter of 2019.

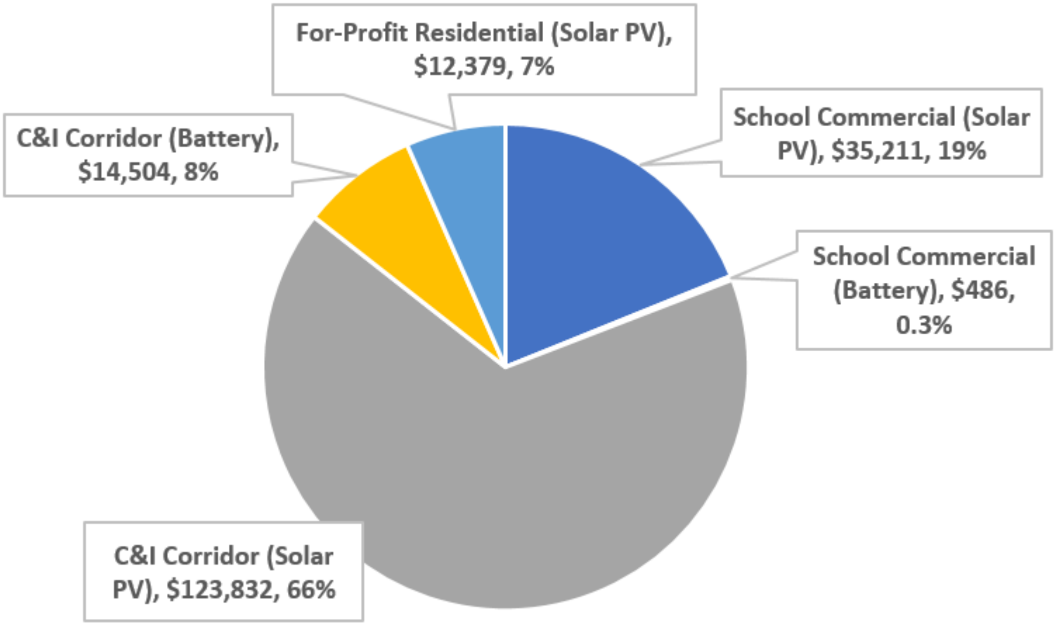
In addition to leveraging SOMAH funds to build solar installations in residential non-profit housing, GRID Alternatives initiates training programs within the community. Through these training programs members of the community would be taught green-collar job-related skills during the installation process. Members of each "cohort" would receive around 224 hours of training throughout the program. Additionally, GRID Alternatives would assist those participating in the program to find jobs following program completion.

The total amount of solar to be installed on non-profit housing buildings is estimated to be 122 kW with a total cost of $380,000. GRID Alternatives would cover the 80 percent of the project costs ($305,000) and the CEC grant would cover 20 percent of the project ($75,000).

DER installed in the educational sector (school and community buildings) would be covered primarily through CEC funds. Tesla would contribute a small amount of cost-share by providing 5 percent of the labor costs. The total cost of placing solar and battery technologies in the school commercial area is $2.14 million. Energy Commission funding would cover $2.1 million of project costs and Tesla would provide $40,000 in cost-share. The school commercial sector will not provide additional cost-share.

Tesla has been a welcome partner on project design development for solar and battery installations. Tesla has deep understanding of the detailed needs for placing solar within a community. Tesla would assist battery and solar installations in the school commercial, commercial and industrial corridor and for-profit residential housing. Under the current design, Tesla would provide 5 percent of the labor costs of implementation in these areas, which is estimated to be $176,000. Figure 61 shows the breakdown of Tesla's cost-share contribution.

Figure 61: Tesla Distributed Energy Resource Provided Cost-Share Breakdown



Source: Altura Associates

Energy Commission funding for solar and battery installations is most effectively leveraged when combined with property owner funding. Because cost-shares are the primary source of funding in implementing ECMs, Energy Commission funds are primarily used in C&I solar and battery installations to meet the Energy Commission budget of $10 million. Under these constraints, the design calls for commercial and industrial property owners to provide 23 percent of the project funding for installing solar and battery technologies at various locations. If initial capital is provided by the C&I sector (with Energy Commission buydown), owners would be able to recoup their initial investment within the first year with the application of federal tax credits. Under this scenario, owners are able to claim full ownership of the system and apply federal tax incentives for the full project cost, resulting in a net positive investment.

The federal tax incentives to be applied are the Investment Tax Credit (ITC) for both solar PV and battery installations and reduced MACRS depreciation. With the ITC program, after paying a 77 percent buydown of the total solar system cost, owners serve to make a return on investment of 3.9, recovering the full capital investment in the first year. The recovery of the battery system investment is dependent on the amount of time the battery is charged by renewables vs. grid, however, a conservative estimate of 75 percent charging with renewables and buydown of 77 percent yields a return on investment of 3.8. These tax benefits offer great incentives for C&I property owners to work with the AEC to purchase solar and battery technologies.

Advanced Energy Community Benefits

The benefits created from these design scenarios are 1) reduced greenhouse gas emissions, 2) reduced strain on the local utility grid, and 3) improved reliability and resiliency within the community:

1) Assuming an avoided emissions factor of 0.000283 metric tons of greenhouse gases per kWh saved, the ECM components is expected to reduce greenhouse gases by 2216 metric tons a year. If net electrical energy use is reduced by 94 percent, greenhouse gas emissions would be reduced by an additional 4,633 metric tons for a total reduction of 6849 metric tons. Under the implementable AEC design, the DER system is capable of reducing emissions by 1.624 metric tons, combining with ECMs to reduce emissions by 3840 metric tons.
2) Implementation of the ECMs would reduce the average electrical utility demand by nearly 900 kW, and reduce peak electrical demand by 1.33 MW. Implementing the full scale solar PV and EES system would reduce average electrical utility demand by an additional 1.87 MW, resulting in a combined reduction of 2.77 MW. Peak demand would decrease by 470 kW. Under the implementable AEC design, average demand would be reduced beyond the ECM scenario by 620 kW, and peak demand would decrease by 300 kW.
3) Although resiliency and reliability are not quantified in this work due to the disparate end uses of energy in the community, resulting in a large difference in the valuation of resiliency and reliability, the implementation of solar PV and EES create a controllable system that can be used to improve local grid performance, and to help guard against grid faults. Combined with the extensive monitoring system to be installed, the foundation for a community scale control system will have been built, allowing for continuous benchmarking and improvement.

This work also examined the potential generation of renewable fuel. The work showed that by using solar PV to generate hydrogen fuel, a large portion of the total electrical demand could be offset. However, the biogas potential from the waste associated only with the local neighborhood can provide only approximately 40 kW of continuous electrical power, meeting approximately 4 percent of the total load.

In total, the considered technologies are not sufficient the convert the Oak View community into a net zero energy community. At most, the community can approach net zero electrical energy. However, due to the large industrial loads at locations with limited opportunity for renewable generation, the gap between the AEC and zero net energy could continue to be large. At present, it is possible to achieve a 94 percent reduction in net electrical energy use, and, at best, an 81 percent reduction when combining electrical and natural gas energy use values. Since the current estimations do not include heating use, this value is projected to be lower. This design, however, is capable of providing better implementation of the solar PV and EES system into the grid while achieving payback in between 15 and 20 years.

CHAPTER 9: Conclusion

The goal of the Huntington Beach AEC project was 1) to develop AEC design tools, and 2) to apply those AEC design tools to the disadvantaged community of Oak View located in Huntington Beach. A series of tasks and objectives were established to accomplish these goals. These objectives and tasks fell into three categories:

1. Model development
2. AEC Design
3. Oak View Community Outreach

Each objective and task was accomplished successfully, resulting in the development of new AEC design tools, an AEC design for the Oak View community, and extensive community outreach that has educated both local residents and businesses about the AEC project, and has also led to the development of green job creation programs. This chapter reviews the work accomplished in during the course of this project, and concludes with lessons learned during the project.

Model Development

Model development resulted in the production of AEC design tools that can be used in future AEC designs. The tools include the URBANopt and DERopt tools and models. The URBANopt tool can be used to explore community wide ECM implementation. The project team has demonstrated that the URBANopt tool can generate detailed simulations and comparisons for a community-scale design problem consisting of more than 300 buildings. The resulting analysis is sufficiently rigorous to study the impacts of and interactions between a wide range of ECM measures. The current version is also capable of exploring the impact of certain DER systems, such as solar PV. Future versions are expected to include an even wider set of ECM and DER options, further consolidating the extent to which the AEC technical design process can be accomplished through a single platform. In addition, other financial components, such as utility rate models, ECM economic performance, and quality of life measures, are currently available through the current version of URBANopt.

Meanwhile, the DERopt tool is capable of optimally designing a DER system for a community of over 300 buildings. By accurately capturing all of the relevant costs, rate structures, and local utility constraints, a feasible community DER design can be developed. The improvements upon the current DER design methods is that the community benefit, versus individual benefit, is maximized. Using a tool like DERopt creates the most benefit of every dollar invested in a DER system, maximizing the overall benefit experienced by the community.

In addition to URBANopt and DERopt, tools for evaluating the renewable energy production were developed. This included a heuristic solar PV potential model that considers realistic constraints, and a renewable gas production model that examines both the biogas potential from local waste streams as well as the production of renewable hydrogen and methane using solar energy. The solar PV capacity model is necessary for any type of AEC design if net zero energy is to be achieved. Understanding the maximum size and location of solar PV is critical to understanding the cost of implementation. In addition, the inclusion of renewable gas production creates the connection between energy loads that cannot be electrified but must still be made sustainable.

Finally, the model development objectives resulted in the development of a grid simulation model that was used to evaluate DER feasibility. Although local grid constraints are included in the DERopt tool, the physics and constraints associated with the electrical grid are too complicated to fully capture in a DER optimization model. Although the constraints included in the DERopt model were based on the most critical factors observed during the development of the grid simulation tool, it is possible for DER implementation and operation to cause a grid operation fault. By pairing the DERopt tool with a fully resolved physical model of the utility grid, it is possible to optimally design a community scale DER system and ensure that feasible operation is achieved.

In addition to the tool development, applicable financial and support mechanisms were explored. While the developed tools focused on the technical aspects of the community, it is important to understand different funding mechanisms, incentives and rebates, and financial structures that can support AEC development. These factors influence the adoption and operation costs, as well as how the benefits are distributed throughout the community and AEC investors. Although these factors do not impact the physical interaction between the buildings, ECMs, DER systems, and the electrical utility grid, they do influence the decision to take certain actions. In addition, it is important to understand AEC financing to make the considered technologies are economically viable.

Finally, an AEC design process was established for developing the technical and financial aspects of the AEC. The critical step in this process is to determine a quantifiable goal for AEC development. This typically will involve cost minimization or profit maximization, but additional goals can also be considered, such as reduce emissions or net energy use, or increase reliability and resiliency. While an AEC development team may wish to pursue all of these goals, the desire to improve economic, environmental, and performance characteristics of a community through AEC implementation will require tradeoffs in certain areas. By defining at the start what the critical goals are, the design process can proceed using quantitative analysis as the basis for decision making.

After the critical design criteria has been determined, the AEC design team must determine not only critical community partners, including both property and business owners, but also nonprofits and organizations that exist to aid local residents and businesses. By determining these crucial community partners, the AEC design team can examine which ECM and DER technologies will provide benefits that support the AEC design goals. Then, using the AEC design tools developed in this work, the AEC development team can predict the baseline energy load of the community, the cost effectiveness of any considered ECMs, and the optimal ECM and DER mix to be adopted throughout the community. This technical design process must occur hand-in-hand with the financial model development to ensure that any technically desirable technology is also financially feasible. In addition, by developing both simultaneously, important equipment and supplier partnerships can be explored during AEC development and prior to implementation

Huntington Beach Advanced Energy Community Design

The design tools developed in this work were applied to the Oak View community. This included the development of more than 300 building models in both the URBANopt and DERopt platforms. The application of these tools resulted in the following design elements:

- Community scale LED upgrades: LED ECMs were found to be highly cost-effective across the entire community. By changing every light fixture to only use LED lighting, electrical energy use could be reduced by 24 percent across the entire community. In addition, simple payback on a community scale LED upgrade is projected to occur within a single year. These benefits are large enough that LED implementation should be done throughout the community regardless of AEC implementation.
- Community scale plug load upgrades: Community scale plug load upgrades consist of multiple different measures taken within each individual building sector. In general, plug load ECMs were found to be less cost effective than LED ECMs. However, in total, plug load ECMs were still found to be economically viable, with a simple payback occurring in between seven to ten years, depending on the number of residents who qualify for SCE CARE rates. Widespread plug load ECMs are projected to reduce electrical energy use by 6 percent. The plug load ECMs and applicable sectors are:
    - High efficiency appliances, such as refrigerators and laundry equipment to be installed across the residential sector.
    - Smart power strips that cut electrical service to connected devices and loads when not in use.
- Community scale DER system: Solar PV and EES systems can be adopted at each location. By considering the optimization of community benefits and the local utility constraints, a community scale DER system was proposed in which the size and location of solar PV and EES was determined. The resulting system was designed to minimize the cost of pushing the community towards net zero energy. Since the proposed technologies affect electrical use directly, the model results were presented in terms of approaching net zero electrical energy. Considering the size of the industrial loads in the community, it is impossible to achieve net zero electrical energy, but net electrical use can be reduced by up to 63 percent resulting in a total reduction in net electrical use by nearly 94 percent when also considering ECMs. The system components consist of:
    - Community wide solar PV that is used to produce renewable electricity, offsetting nonrenewable generation supplied by the local utility grid. In addition to providing renewable energy, certain solar PV installations are designed to be

mounted on shading structures, providing shading in parking lots. The additional amenity reduces the heating of community parking lots and blacktop areas, and provides a service to local residents, employees, and volunteers.

  - EES that supports solar PV generation and enables feasible DER integration with the utility grid. The EES system is optimized to minimize cost while supporting the goal of approaching net zero energy, resulting in a tailor made system perfectly suited for the Oak View community.

- Community scale energy data acquisition and management: A part of AEC development is to determine that the projected benefits are realized, and to understand differences between the modeled and design system, and the actual community. To support this, a community wide energy data capture system will be implemented. This system will allow for continuous benchmarking of both the AEC design tools, but more importantly, the AEC performance. By implementing the data acquisition system, community energy can be managed in a way such that any DER systems are operated to maximize community benefit.

In addition to these components, both the production of renewable gas and an electric car share service were explored. The results of renewable gas production showed that the conversion of solar PV into fuel, such as hydrogen, could be used to meet a large portion of the community energy demand, or be injected into the natural gas pipeline. However, the currently available processes necessary for the renewable fuel production and injection into the pipeline are prohibitively expensive for the scale of the project. Biogas production using the waste streams transferred through the waste transfer facility also have the potential to produce a significant stream of renewable fuel. However, when only considering waste from the Oak View community, the amount of fuel generation decreases to approximately 100 kW average output. Finally, the car share service was projected to need 18 vehicles. However, due to difficulty with securing parking throughout the community, the plan will not be pursued at the current time.

Community Outreach

In addition to the technical design tools and Oak View AEC design, the team also achieved extensive outreach throughout the community. This included:

- The development of digital and print media used to advertise the project to various community members, ranging from school children to business owners. The most successful item was an AEC-themed set of Loteria cards that children are still using.
- The execution of multiple outreach events, including an adult workshop and child education program. These programs were used to educate the community about the AEC project, and to educate adults about different AEC concepts and utility programs available to them. The children's education program was a success in which 10 classes were held to educate students about different energy concepts.
- A workforce development plan in which more than 40 green collar jobs were described in detail, including education required, benefits, and typical types of work tasks. In addition to the job descriptions, the team worked on identifying barriers to workforce

development, and also determined methods and classes that can help residents overcome these barriers.

In addition to these outreach items, the team conducted numerous site visits and energy audits in which the technical part of the time was able to interact with the community, gain exposure to the currently existing energy infrastructure, and solicit AEC design ideas from the community.

Lessons Learned

During the Huntington Beach AEC design project, the design team periodically reflected on the design methodology, process, and implementation. Through these periods of reflection, a set of lessons learned became clear to both streamline and improve the AEC design process. The following lessons learned are considered by the team to be extendable to other AEC projects and necessary to future development.

- Early relationship establishment with community organizations: Multiple community organizations operate within the Oak View community, including nonprofit housing and resident advocacy groups, public educational institutions, and community centers. The critical component of securing community support for the project was the early and often engagement of these organizations. Through establishment and development of these relationships, the team was able to have an open dialogue with the community in which residents' concerns and desires could be solicited. By maintaining these lines of communication, trust between the community and the project team was built, facilitating support throughout the community.
- Early development of commercial and industrial energy improvements: Part of the current AEC project included the extensive development of AEC design tools. The development of these tools was time intensive, resulting in the ultimate AEC design being shifted towards the end half of the project. This created a challenge when approaching implementation due to a reduced amount of time for internal review of the proposed AEC technologies to be implemented at each commercial and industrial location. While this is not a challenge for every organization, it can be for some for which sufficient administrative bandwidth does not exist to quickly review proposed AEC related improvements, or other organizations that require multiple levels of approval. In addition, future AEC designs should be built using design tools developed in this initial design and development phase, resulting in a much quicker design turnaround time.
- The need for technical tools for predicting AEC technology impacts: A major goal for this project was the development of community-scale energy modeling tools. During the development, it became clear that to capture the interaction between various technologies, these tools must be developed. Although the financial aspects will ultimately determine the final AEC design, the cost value of individual components cannot be accurately captured unless how each technology fits together can be effectively captured. In addition, these tools are necessary when dealing with finite

resources, such as electrical grid capacity. Without considering the technical limitations of the local utility grid, maximum individual benefit can be gained by first adopters of technologies like solar PV. This, however, can result in suboptimal community scale design. If maximum benefit for the entire community is to be realized, then community scale tools must be used to simultaneously consider benefits to all utility customers.

- The establishment of quantifiable criteria for making AEC development decisions: A common reaction from an AEC design team is the desire to minimize cost and environmental impact while maximizing reliability and resiliency. Considering that each of these goals alone can yield different outcomes, it is important at the start to clearly define what the ultimate goal of the AEC is.

When expanding the AEC design to other cities, it is important to use tools like URBANopt and DERopt to establish the technical design. Use of these tools is critical to linking the financial and technical aspects of the project, while providing a quantifiable pathway for implementing other desires presented to the AEC developers by the community. By using these tools, the complex interactions between various technologies can be determined, allowing for the environmental and economic benefits each individual technology group to be determined.

LIST OF ACRONYMS

Term	Definition
AEC	Advanced Energy Community
APS	Advanced power strips
C&I	Commercial and industrial
CAFATFA	California Alternative Energy and Advanced Transportation Financing Authority
CAPOC	Community Action Partnership Orange County
CCA	Community choice aggregation
CDBG	Community Development Block Grant
DER	Distributed energy resource
DES	Distributed energy system
DOE WAP	Department of Energy Weatherization Assistance Program
DR	Demand response
ECM	Energy conservation measure
ECR	Enhanced Community Renewables
EE	Energy efficiency
EES	Electric energy storage
EPIC (Electric Program Investment Charge)	The Electric Program Investment Charge, created by the California Public Utilities Commission in December 2011, supports investments in clean energy technologies that benefit electricity ratepayers of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company.
ESCO	Energy service company
ESPC	Energy Savings Performance Contract
EV	Electric vehicle
F&B	Finance and business
FRC	Family Resource Center

Term	Definition
HB AEC	Huntington Beach Advanced Energy Community
HUD	Housing and Urban Development
HVAC	Heating, ventilation, and air conditioning
IEA	International Energy Agency
LI-HEAP	Low Income Home Energy Assistance Program
LIWP	Low Income Weatherization Program
MIDI	Middle income direct install
NCPPP	National Council for Public-Private Partnership
NEM	Net energy metering
NREL	National Renewable Energy Laboratory
OCCHC	Orange County Community Housing Corporation
P3	Public private partnerships
PACE	Property Assessed Clean Energy Program
PPA	Power purchase agreement
PPL	Plug and process load
PRP	Preferred Resource Pilot
PV	Photovoltaic
REEL	Residential Energy Efficiency Loans
RPF	Repeated power flow
SASH	Single-family Affordable Solar Homes Program
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
Smart Grid	Smart grid is the thoughtful integration of intelligent technologies and innovative services that produce a more efficient, sustainable, economic, and secure electrical supply for California communities.
SNAP	Supplemental Nutrition Assistance Program
SOMAH	Solar on Multifamily Affordable Housing Program

Term	Definition
SPE	Special purpose entity
SSI	Supplemental Security Income
VNEM	Virtual net energy metering

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APPENDIX A:
DERopt Formulation

Model Sets, Parameters, and Decision Variables

The applicable sets for the optimization model are:

- $n \in N$: Set of all months
- $m \in M$: Set of all summer months ($M \subset N$)
- $t \in T_n$: Set of all 15 minute increments in month n
- $o \in O_m$: Set of all 15 minute increments during on-peak in summer month m ($O \subset T$)
- $p \in P_m$: Set of all 15 minute increments during mid-peak in summer month m ($P \subset T$)
- $k \in K$: Set of all generator types
- $b \in B$: Set of all buildings
- $i \in I$: Set of all transformers
- $j \in J_i$: Set of buildings that are connected to transformer i ($J \subset B$)
- $x \in X$: Set of electrical notes (x, x' notation used to indicate separate nodes)

The applicable parameters and decision variables for the optimization model can be seen in Table A-1**Error! Reference source not found.** and Table A-2 respectively. Note that the model is formed as a linear program.

Table A-1: List of Parameters used in DERopt

Parameter	Description	Units	Value
$E_{Bldg\ Elec,t,b}$	Electrical demand at building b, at time t	kWh	Based on predicted model value
A_b	Area available for solar PV installation at building b	m^2	Based on methods described in Chapter 4
$e_{solar,t}$	Average available insolation at time t	kWh/m^2	Taken from [51]
$C_{grid,t,b}$	Electrical utility energy charge at time t at building b	$/kWh	Refer to [52]
$C_{DC,n}$	Non-TOU demand charge in month n	$/kW	14.88
$C_{onDC,m}$	On-peak demand charge in summer month m	$/kW	23.74
$C_{midDC,m}$	Mid-peak demand charge in summer month m for building b	$/kW	6.55

Parameter	Description	Units	Value
$C_{NEM,t,b}$	Net energy metering price at which electrical utility purchases energy from building b at time t	$/kWh	Energy charge $C_{grid,t}$ minus transmission and distribution cost
$C_{wsale,t,b}$	Wholesale price at which electrical utility purchases energy from building b at time t	$/kWh	0.03
$C_{cap\ PV,k,b}$	Capital cost for solar PV system of type k purchased at building b	$/kW	3100 for rooftop, 3600 for car shade
$C_{om\ PV}$	O&M Cost for solar PV system	$/kWh	.001
$\eta_{PV,k}$	Efficiency of PV of type k efficiency at nominal conditions	%	18
$C_{cap\ EES,b}$ / $C_{cap\ REES,b}$	Capital cost of EES/REES at building b	$/kWh	700
$C_{om\ EES\ chrg}$ / $C_{om\ REES\ chrg}$	Cost to charge EES	$/kWh	0.001
$C_{om\ EES\ dchrg}$ / $C_{om\ EES\ chrg}$	Cost to discharge EES	$/kWh	0.001
α_{EES} / α_{REES}	Retained EES/REES storage between 15 minute periods	%	99.99
$\eta_{EES\ chrg}$ / $\eta_{REES\ chrg}$	EES/REES charging efficiency	%	95
$\eta_{EES\ dchrg}$ / $\eta_{REES\ dchrg}$	EES/REES charging efficiency	%	95
$\bar{\delta}_{EES}$ / $\bar{\delta}_{REES}$	Maximum EES/REES state of charge	% of purchased capacity	95
$\underline{\delta}_{EES}$ / $\underline{\delta}_{REES}$	Minimum EES/ REES state of charge	% of purchased capacity	10
$\bar{\mu}_{EES}$ / $\bar{\mu}_{REES}$	Maximum EES/ REES charging rate	% of purchased capacity	25
$\underline{\mu}_{EES}$ / $\underline{\mu}_{REES}$	Maximum EES/ REES discharging rate	%of purchased capacity	25
$P_{rated,i}$	Rating of transformer i	kVa	Refer to Chapter 0
pf	Building power factor	n/a	0.9
α_T	Transformer rating protection percentage	%	1

Table A-2: List of Decision Variables used in DERopt

Decision Variable	Description	Units
$e_{grid,t,b}$	Electricity imported from the grid to building b at time t	kWh
$P_{max,n,b}$	Maximum monthly demand during month n at building b	kW
$P_{on\ max,m,b}$	Maximum on-peak demand during summer month m and building b	kW

$P_{mid\ max,m,b}$	Maximum mid-peak demand during summer month m at building b	kW
$P_{max\ PV,k,b}$	Solar PV capacity of type k adopted at building b	kW
$e_{PV\ elec,t,b}$	Energy generated by solar PV at time t at building b	kWh
$e_{PV\ NEM,t,b}$	Energy exported under NEM rates at time t from building b	kWh
$e_{PV\ wsale,t,b}$	Energy exported under wholesale rates at time t from building b	kWh
$E_{EES,b}$	EES capacity adopted at building b	kWh
$e_{EES\ SOC,t,b}$	EES state of charge t time t at building b	kWh
$e_{EES\ chrg,t,b}$	Energy charged to EES at time t at building b	kWh
$e_{EES\ dchrg,t,b}$	Energy discharged to EES at time t at building b	kWh
$E_{REES,b}$	REES capacity adopted at building b	kWh
$e_{REES\ SOC,t,b}$	REES state of charge t time t at building b	kWh
$e_{REES\ chrg,t,b}$	Energy charged to REES at time t at building b	kWh
$e_{REES\ dchrg,t,b}$	Energy discharged to REES at time t at building b	kWh
$e_{REES\ NEM\ dchrg,t,b}$	Energy exported from REES at NEM rates at time t at building b	kWh
$P_{t,i}$	Power flowing through transformer I at time t	kVa

The model objective function is shown in Equation (2). This equation shows the cost to purchase electricity from the local utility, the cost to purchase and operate and DER, as well as the benefit created by exporting electricity back to the grid under both net energy metering (NEM) and wholesale rates. Note that the objective of the optimization can be altered to reflect user intentions. For example, another potential cost function could be to minimize net imports, total imports, primary fuel use, or both greenhouse or pollutant emissions.

$$
\begin{aligned}
\boldsymbol{minimize} \sum_b \Bigg(& \sum_t C_{grid,t} e_{grid,t,b} + \sum_n C_{DC,n} P_{max,n,b} + \sum_m C_{on\ DC,m} P_{on\ max,m,b} \\
& + \sum_m C_{mid\ DC,m} P_{mid\ max,m,b} + \sum_k C_{cap\ PV,k} P_{max\ PV,k,b} \\
& + \sum_t C_{om\ PV} e_{PV\ elec,t,b} - \sum_t C_{NEM,t} e_{PV\ NEM,t,b} - \sum_t C_{wsale} e_{PV\ wsale,t,b} \\
& + C_{cap\ EES} E_{EES,b} + \sum_t C_{om\ EES\ dchrg} e_{EES\ chrg,t,b} \\
& + \sum_t C_{om\ EES\ chrg} e_{EES\ dchrg,b} + C_{cap\ REES} E_{REES,b} \\
& + \sum_t C_{om\ REES\ dchrg} e_{REES\ chrg,b} + \sum_t C_{om\ REES\ chrg} e_{REES\ dchrg,b} \\
& - \sum_t C_{NEM,t} e_{\ REES\ NEM\ dchrg,b} \Bigg)_b
\end{aligned}
\tag{2}
$$

General Constraints

Multiple DER optimization models have been presented in academic literature. In general, each optimization contains a cost function similar to what is presented in Equation (2) such that a given load is always met while maintaining feasible operation of all generating and utility assets. Equation (3) requires that the building load b at times t, plus any EES charging, is met through utility imports, currently available solar production sent to the building, and the discharging of any EES or REES assets. Equations (4), (5), and (6) relate electrical imports to both nonTOU and TOU demand charges.

$$e_{grid,t,b} + \mathrm{e}_{\mathrm{PV\ elec,t,b}} + e_{EES\ dchrg,t,b} + e_{REES\ dchrg,t,b} = E_{Bldg\ Elec,t,b} + e_{EES\ chrg,t,b} \tag{3}$$

$$4e_{grid,t,b} \le P_{max,n,b} \tag{4}$$

$$4e_{grid,o,b} \le P_{on\ max,m,b} \tag{5}$$

$$4e_{grid,p,b} \le P_{mid\ max,m,b} \tag{6}$$

The two equations that constrain solar PV adoption and operation are shown in Equations (7) and (8). Equation (7) limits PV production by the installed capacity and available insolation. Equation (8) limits the size of the PV system

$$e_{grid,t,b} + \mathrm{e}_{\mathrm{PV\ elec,t,b}} + \mathrm{e}_{\mathrm{PV}wsale,t,b} + e_{PV\ NEM,t,b} + e_{REES\ chrg,t,b} \le \sum_k e_{solar,t} P_{\max PV,k,b} \tag{7}$$

$$\textstyle\sum_k P_{\max PV,k,b}/\eta_{PV,k} \le P_{max,n,b} \tag{8}$$

Both the EES and REEES share similar types of constraints. Equations (9) and (14) show the energy balance for the EES and REES respectively. The only difference between these two equations is that stored energy in the REES can be discharged as export back to the grid, as captured with the $e_{REES\ NEM\ dchrg,t,b}$ variable Equations (10) and (15) limit the maximum state of charge by the installed capacity for the EES and REES respectively, whereas Equations (11) and (16) limit the minimum state of charge for the same systems. Equations (11) and (17) limit the maximum discharge rate by the size of the adopted battery, and Equations (13) and (18) limit charging to the battery for the EES and REES system respectively.

$$e_{EES\ SOC,t,b} = \alpha_{EES} e_{EES\ SOC,t-1,\mathrm{b}} + \eta_{EES\ chrg} e_{EES\ chrg,t,b} - \frac{e_{EES\ dchrg}}{\eta_{EES\ dchrg}} \tag{9}$$

$$e_{EES\ SOC,t,b} \leq \bar{\delta}_{EES} E_{EES,b} \tag{10}$$

$$e_{EES\ SOC,t,b} \geq \underline{\delta}_{EES} E_{EES,b} \tag{11}$$

$$e_{EES\ dchrg,t,b} \leq \bar{\mu}_{EES} E_{EES,b} \tag{12}$$

$$e_{EES\ chrg,t,b} \leq \underline{\mu}_{EES} E_{EES,b} \tag{13}$$

$$e_{REES\ SOC,t,b} = \alpha_{REES}\, e_{REES\ SOC,t-1,\mathrm{b}} + \eta_{REES\ chrg} e_{REES\ chrg,t,b} - \frac{e_{REES\ dchrg,t,b} + e_{REES\ NEM\ dchrg,t,b}}{\eta_{REES\ dchrg}} \tag{14}$$

$$e_{REES\ SOC,t,b} \leq \bar{\delta}_{REES}\, E_{REES\ ,b} \tag{15}$$

$$e_{REES\ SOC,t,b} \geq \underline{\delta}_{REES}\, E_{REES\ ,b} \tag{16}$$

$$e_{REES\ dchrg,t,b} \leq \bar{\mu}_{REES}\, E_{REES\ ,b} \tag{17}$$

$$e_{REES\ chrg,t,b} \leq \underline{\mu}_{REES}\, E_{REES\ ,b} \tag{18}$$

Equation (19) limits the export of electricity under NEM rates by the value of imported electricity. Since maximum NEM value depends on the quantity and cost of imported electricity, two possible constraints exist that limit NEM credit. While Equation (19) captures the value limitations, the explicit energy limit is not present in the current optimization. During model development, it was determined that the credit value associated with NEM created the constraint that limited NEM credit, resulting in inconsistent use of a NEM energy constraint. As a result, this constraint was removed from the optimization to ease computational difficulty.

$$\sum_t C_{NEMt,b} * \left(e_{PV\ NEM,t,b} + e_{REES\ NEM\ dchrg,t,b}\right) \leq \sum_t C_{grid,t,b} * e_{grid,t,b} \tag{19}$$

Transformer Constraints

In the multi-nodal approach, each node represents a distribution transformer. This transformer then feeds a cluster of buildings and also has DER connected to it. **Error! Reference source not found.** in Chapter 4 illustrates one such transformer node, namely T1, which supplies a building load, BLDG1. A solar PV and battery Electric Energy Storage (EES) are associated with BLDG1. For each building, the following power balance applies, for each time step *t*.

We observe from **Error! Reference source not found.** that the power flowing across t ransformer T1 ($P_{t,1}$) is a balance of all power flows going in and out of that node (for each time step t). Generalizing this example, the power through a given transformer i ($P_{t,i}$) is the sum of power flows pertaining to the b buildings connected to that transformer. Equation (20) shows this relationship.

$$P_{t,i} = \sum_{j=1}^{J} \frac{e_{grid,t,b}}{pf} - \mathrm{e_{PV\ Nem,t,b}} - e_{PV\ wsale,t,b} - e_{REES\ NEM\ dchrg,t,b} \tag{20}$$

The power capacity of a transformer is limited by the amount of current it can carry continuously, at rated voltage without exceeding the design temperature. Ratings are measured in kilovolt-amperes, or kVA, which is the total (apparent) power that flows through its windings, which includes active (kW) and reactive (kVar) power flows [53]. Transformer overloads are typically acceptable for a limited amount of time. Nonetheless, any overload will affect the equipment lifespan and maintenance needs. In [54], permissible loading curves for transformers are shown according to different ambient temperatures. In our analysis, the loading limit assumed is 100 percent of rated power.

Therefore, constraints pertinent to transformer rating limits are added to the optimization. For each time step, the power flowing through a given transformer n ($P_{t,i}$) can't exceed a given percentage (α_T), of its kVA rating ($P_{rated,i}$). Thus, α_T is a coefficient between 0 and 1. For example, α_T = 0.9 the transformer load won't exceed 90 percent of its kVA rating. Equation (21) limits net energy transformer through the transformer to be less than the transformer rating.

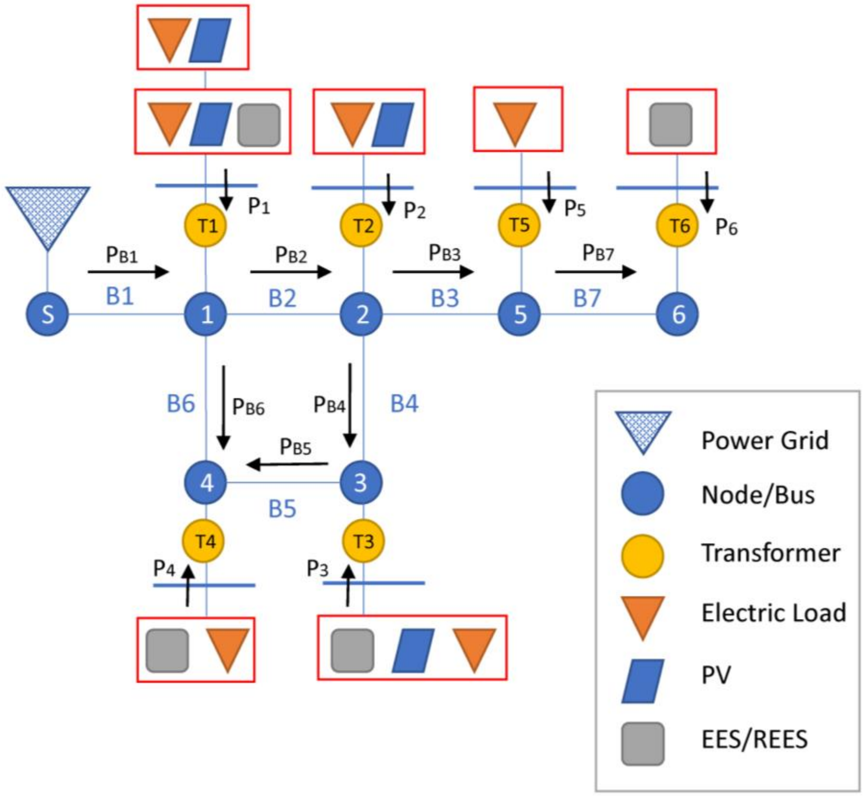
$$-P_{rated,i} * \alpha_T \leq P_{t,i} \leq P_{rated,i} * \alpha_T \tag{21}$$

Note that the transformer can be importing power ($P_{t,i}$ is positive) or exporting power ($P_{t,i}$) is negative), this is why Equation (21) must include the negative lower bound: power flows must be limited in both directions. Ultimately, all buildings and DER will have a transformer, or node, associated with it. Therefore, the optimal DER allocation and dispatch will always respect the distribution transformer ratings.

Ampacity Constraints

The network electric wires and conductors in an electric distribution network also have physical limits to power flows and can only withstand a limited amount of power (or current) flows. If the power (or current) flowing in a circuit is higher than its rated ampacity (i.e., the maximum rated current allowed), there will likely be damages in the electric insulation of this circuit due to the temperature increase caused by the resistive heating (Joule effect). In DERopt, these limits are translated into circuit ampacity constraints, which will limit the amount of current that can flow in each circuit branch within the network.

Figure A-1: Schematics for Ampacity Constraints



Source: University of California, Irvine

Consider the schematics of an example network that can be modeled in DERopt, shown in Figure A-1. In this example; there are six nodes that are grid-tied in node S, which is the slack node. Each node is then associated with a transformer, which feeds a combination of loads and DER. The six nodes are interconnected by seven branches (B1 through B7) in a meshed network (i.e., a loop exists between nodes 1, 2, 3, and 4). The branch power flows (PB1 through PB7) are also shown in Figure A-1. The branch flow is taken as positive when flowing from the node of lower number to the node with a higher number. We are interested in limiting the branch flows (PB1 through PB7).

As DERopt is a Mixed Integer Linear Program (MILP), linearized power flow equations must be used to solve the power flow problem. For this, the simplified DC Power flow (DCPF) solution method was chosen. DCPF is widely used in optimal power flow problems, such as optimal (economic) dispatch. The main advantage of using DCPF in optimization applications comes from its reduced problem size and complexity (fewer variables, and linearity), as opposed to the non-linear, or numerical, AC power flow (ACPF) methods. The simplicity of the DCPF, however, comes with the tradeoff of a reduced accuracy as compared to the non-linear ACPF. The reduced accuracy stems from a few primary assumptions and approximations, which are the following [55]:

- All bus voltages are very close to 1.0 p.u.

- All bus voltage angle differences ($\delta = \theta_x - \theta_{x'}$) are very small
  - $\sin(\delta) \cong \delta$
  - $cos(\delta) \cong 1$
- In DC power flow, only active power (P) flows exist
- The lines are lossless, or its resistance is zero (R = G = 0)

Thus, the per-unit power flow injections at each node x (P_x) in the DCPF formulation are:

$$P_x = \sum_{\substack{x=1 \\ x \neq x'}}^{X} B_{x,x'} (\theta_x - \theta_{x'}) \tag{22}$$

Where P_x are the per-unit nodal injections, which are calculated using Equation (20). $B_{x,x'}$ is the susceptance matrix (i.e., the imaginary part of the admittance matrix). A detailed explanation on how to obtain the admittance matrix of a network is given in [55] and [56]. $\theta_x, \theta_{x'}$ are the voltage phasor angles of the two adjacent buses x and x', respectively. For the DCPF in this analysis, we assume that all nodal injections P_x are known (i.e., all buses are PQ type). All line susceptances are also known, thus $B_{x,x'}$ is known. The unknown variables are the voltage phase angles, θ, at each node. The matrix formulation of the DCPF problem in DERopt is as follows:

$$\bar{\theta}' = (\bar{B}')^{-1} \bar{P_x} \tag{23}$$

Where $\bar{\theta}'$ is the vector of all (ordered) phase angles, excluding the slack node (node S). $\bar{B}'$ is the reduced susceptance matrix of the system (i.e., $B_{x,x'}$ excluding node S), and $\bar{P_x}$ is the vector of bus nodal injections, also excluding the slack node power injection.

Once $\bar{\theta}'$ is calculated, then the branch power flows ($P_{x.x'}$) can be calculated by employing just one term of Equation (23):

$$P_{x,x'} = B_{x,x'}(\theta_x - \theta_{x'}) \tag{24}$$

Where $P_{x,x'}$ is the active power flow from bus x to bus x'. To generalize the calculation above, we can write Equation (24) in matrix form. The branch flows $P_{x,x'}$ are ordered (P_1, P_2, and so on) in a column vector $\overline{P_B}$ of dimension Mx1.

$$\overline{P_B} = (\bar{D} \times \bar{A}) \times \bar{\theta}' \tag{25}$$

$\bar{D}$ is a M x M matrix with the diagonal (m,m) elements being the negative of the susceptance of the m^th^ branch, and non-diagonal elements equal to 0. $\bar{A}$ is the node-arc incidence matrix, M x N-1. In the $\bar{A}$ matrix, the element (m,j) is 1 if the m^th^ branch begins at node j, -1 of the m^th^ branch terminates at node j, and 0 otherwise. The $\bar{A}$ matrix is also known as the adjacent or connection matrix. A more detailed explanation on the development of the $\bar{A}$ matrix is given in [55] and [56]. $\bar{\theta}'$ is the (reduced) vector of known nodal voltage phase angles. The order (nodes and branch numbering) used for P_B must be consistent with the order used in $\bar{D}$ and $\bar{A}$.

Finally, using the approximations $|V_x| \approx 1$ and $Q_{x,x'} = 0$ [55], the branch current magnitudes $I_{x,x'}$ may be approximated to the magnitudes of the active power flows $P_{x,x'}$, i.e.:

$$I_{x,x'} = \left(\frac{P_{x,x'} + jQ_{x,x'}}{V_x}\right)^* \rightarrow \boxed{\left|I_{x,x'}\right| \approx \left|P_{x,x'}\right|} \quad (26)$$

Thus, in DERopt, the ampacity constraints are implemented for all M branches as follows:

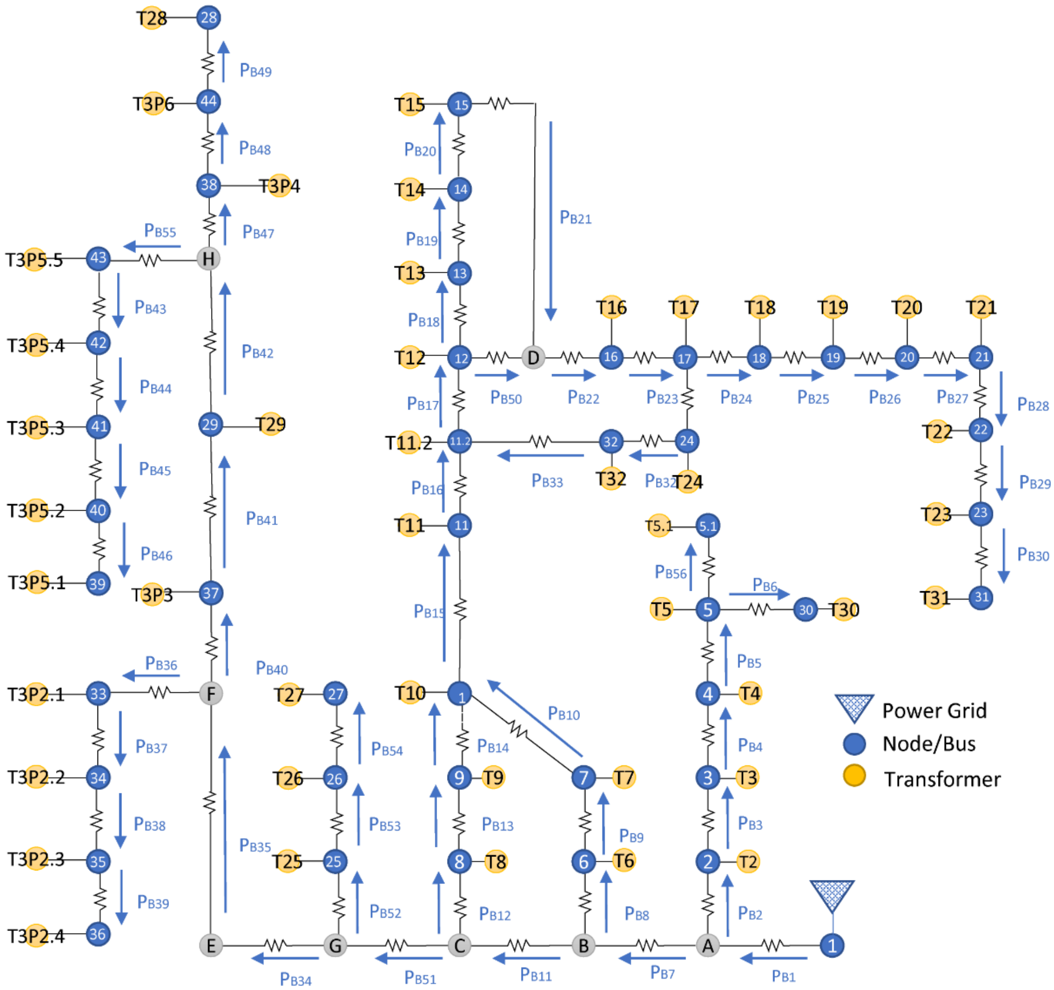
$$-1 * I_{rated} \leq |P_x| \leq I_{rated} \quad (27)$$

Where P_x are elements of $\overline{P_B}$ and I_{rated} is the per unit ampacity rating for a given circuit, i.e., the rating in amps divided by the base current. Note that only Equation (27) is included in the DERopt optimization model. Equations (22) through (26) are required to set up the line ampacity constraints.

Oak View Advanced Energy Community grid model

The Oak View AEC electrical power system was modeled in DERopt, as seen in the schematics of Figure A-2.

Figure A-2: Oak View AEC Power System Network as Modeled in DERopt



Source: University of California, Irvine

The network modeled is composed of 53 nodes, 56 branches, and 45 transformers. The model considers only the area served by the Smeltzer 12 kV circuit since this is the main circuit that feeds the AEC loads. The Slack node is node 1, and it represents the point of connection with the wide-area grid. The base values assumed for voltage, power, and impedance are $V_b = 230\ kV$ and $S_b = 100\ MVA$, and $Z_b = 529\ ohm$, respectively. A total of 314 building loads were connected to their respective service transformers. The individual building loads use as inputs 15-minute load profiles, in kW, which are outputs from URBANopt (UO). DERopt aims to optimally allocate an area-limited PV capacity and also an unlimited BESS capacity into the Oak View AEC power system to minimize total cost over the operating period of one year.

The conductor impedance values assumed for each branch of Figure A-2 are listed in Numbers in feet.

Source: University of California, Irvine

, the conductor types used in the model are (1) 1/0 AWG, (2) 2/0 AWG, (3), 3/0 AWG, and (4), #4 AWG. The AEC transformer ratings and impedances are listed in Numbers in feet.

Source: University of California, Irvine

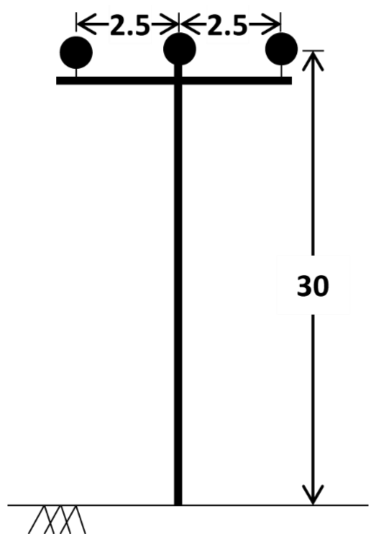
.

For this analysis, the entries of B_{kj} include the branch admittances (y_{kj}) between branches k and j, and the shunt admittances of the transformer installed in node k (y_{T_k}). The branch resistances (R) and reactances (X) used to calculate y_{kj} (Equation (10) are shown in Table A-3. All X and R values were obtained from the ETAP AEC model, where all lines were assumed to be overhead and with a geometry described in Figure A-3. The transformer resistances (R_t) and reactances (X_t) used to calculate y_{T_k} (Equation(28) are shown in Table.

$$y_{kj} = \frac{1}{R + jX} * \frac{1}{Z_b} \tag{28}$$

$$y_{T_k} = \frac{1}{R_T + jX_T} * \frac{1}{Z_b} \tag{29}$$

Figure A-3: Overhead Circuit Configuration for AEC Model.



Numbers in feet.

Source: University of California, Irvine

Table A-3: AEC Oak View DERopt model – Conductor length and Impedance

Branch	Length (miles)	Conductor type	r (ohm/mile)	x (ohm/mile)	R (ohm)	X (ohm)
B1	0.09	3	0.6337	0.65719	0.057033	0.0591471
B2	0.03	4	2.546	0.74129	0.07638	0.0222387
B3	0.03	4	2.546	0.74129	0.07638	0.0222387
B4	0.03	4	2.546	0.74129	0.07638	0.0222387
B5	0.03	4	2.546	0.74129	0.07638	0.0222387

B6	0.03	4	2.546	0.74129	0.07638	0.0222387
B7	0.06	2	0.7983	0.67094	0.047898	0.0402564
B8	0.03	4	2.546	0.74129	0.07638	0.0222387
B9	0.03	4	2.546	0.74129	0.07638	0.0222387
B10	0.06	4	2.546	0.74129	0.15276	0.0444774
B11	0.06	1	1.006	0.68535	0.06036	0.041121
B12	0.03	4	2.546	0.74129	0.07638	0.0222387
B13	0.06	4	2.546	0.74129	0.15276	0.0444774
B14	0.07	4	2.546	0.74129	0.17822	0.0518903
B15	0.06	4	2.546	0.74129	0.15276	0.0444774
B16	0.05	4	2.546	0.74129	0.1273	0.0370645
B17	0.1	4	2.546	0.74129	0.2546	0.074129
B18	0.05	4	2.546	0.74129	0.1273	0.0370645
B19	0.04	4	2.546	0.74129	0.10184	0.0296516
B20	0.04	4	2.546	0.74129	0.10184	0.0296516
B21	0.04	4	2.546	0.74129	0.10184	0.0296516
B22	0.03	4	2.546	0.74129	0.07638	0.0222387
B23	0.03	4	2.546	0.74129	0.07638	0.0222387
B24	0.05	4	2.546	0.74129	0.1273	0.0370645
B25	0.05	4	2.546	0.74129	0.1273	0.0370645
B26	0.05	4	2.546	0.74129	0.1273	0.0370645
B27	0.05	4	2.546	0.74129	0.1273	0.0370645
B28	0.05	4	2.546	0.74129	0.1273	0.0370645
B29	0.05	4	2.546	0.74129	0.1273	0.0370645
B30	0.05	4	2.546	0.74129	0.1273	0.0370645
B31	0.05	4	2.546	0.74129	0.1273	0.0370645
B32	0.05	4	2.546	0.74129	0.1273	0.0370645
B33	0.05	4	2.546	0.74129	0.1273	0.0370645
B34	0.06	1	1.006	0.68535	0.06036	0.041121
B35	0.03	4	2.546	0.74129	0.07638	0.0222387
B36	0.03	4	2.546	0.74129	0.07638	0.0222387
B37	0.01	4	2.546	0.74129	0.02546	0.0074129
B38	0.01	4	2.546	0.74129	0.02546	0.0074129
B39	0.01	4	2.546	0.74129	0.02546	0.0074129
B40	0.06	1	1.006	0.68535	0.06036	0.041121
B41	0.06	4	2.546	0.74129	0.15276	0.0444774
B42	0.03	4	2.546	0.74129	0.07638	0.0222387
B43	0.01	4	2.546	0.74129	0.02546	0.0074129
B44	0.01	4	2.546	0.74129	0.02546	0.0074129

B45	0.01	4	2.546	0.74129	0.02546	0.0074129
B46	0.01	4	2.546	0.74129	0.02546	0.0074129
B47	0.03	4	2.546	0.74129	0.07638	0.0222387
B48	0.03	4	2.546	0.74129	0.07638	0.0222387
B49	0.03	4	2.546	0.74129	0.07638	0.0222387
B50	0.06	4	2.546	0.74129	0.15276	0.0444774
B51	0.06	1	1.006	0.68535	0.06036	0.041121
B52	0.03	4	2.546	0.74129	0.07638	0.0222387
B53	0.03	4	2.546	0.74129	0.07638	0.0222387
B54	0.03	4	2.546	0.74129	0.07638	0.0222387
B55	0.01	4	2.546	0.74129	0.02546	0.0074129
B56	0.03	4	2.546	0.74129	0.07638	0.0222387

Table A-4: Transformer ratings, resistances, and reactances.

Transformer	Rating (kVA)	R_T (ohm)	X_T (ohm)
T1P-2	25	1.626	1.626
T1P-3	25	1.626	1.626
T1P-4	25	1.626	1.626
T1P-5	25	1.626	1.626
T3P-5.1-Residential	100	1.199	3.5
T1P-6	50	1.307	2.013
T1P-7	50	1.307	2.013
T1P-8	50	1.307	2.013
T1P-9-Residential	100	1.199	3.5
T1P-10	50	1.307	2.013
T1P-11	37.5	1.307	2.013
T3P-11.2	300	0.893	2.759
T1P-12	15	1.626	1.626
T1P-13	50	1.307	2.013
T1P-14	50	1.307	2.013
T1P-15	50	1.307	2.013
T1P-16	25	1.626	1.626
T1P-17	25	1.626	1.626
T1P-18	50	1.307	2.013
T1P-19	50	1.307	2.013
T1P-20	50	1.307	2.013
T1P-21	15	1.626	1.626
T1P-22	15	1.626	1.626
T1P-23	37.5	1.307	2.013

T1P-24	50	1.307	2.013
T1P-25	37.5	1.307	2.013
T1P-26	100	1.199	3.5
T1P-27	15	1.626	1.626
T1P-28	25	1.626	1.626
T1P-29	25	1.626	1.626
T1P-30	75	1.199	3.5
T1P-31	75	1.199	3.5
T1P-32	50	1.307	2.013
T3P-2.1	75	1.199	3.5
T3P-2.2	150	0.99	3.565
T3P-2.3	150	0.99	3.565
T3P-2.4	150	0.99	3.565
T3P-3	1500	0.802	5.694
T3P-4	75	1.199	3.5
T3P-5.1-Commercial	150	0.99	3.565
T3P-5.2	50	1.307	2.013
T3P-5.3	350	1.001	5.103
T3P-5.4	100	1.199	3.5
T3P-5.5	150	0.99	3.565
T1P-6-Commercial	75	1.199	3.5

APPENDIX B: Advanced Energy Community Case Study Results

Case A: Maximize ECMs / Maximize Solar PV / Battery Storage for PV – No Budget Constraints

The case study shows to highlight the full energy savings potential of an optimized ECM roll-out while maximizing the solar potential and the savings generated through battery storage for the solar PV. This case remains unconstrained in budget to fully analyze the realized energy potential of utilizing these strategies in the community.

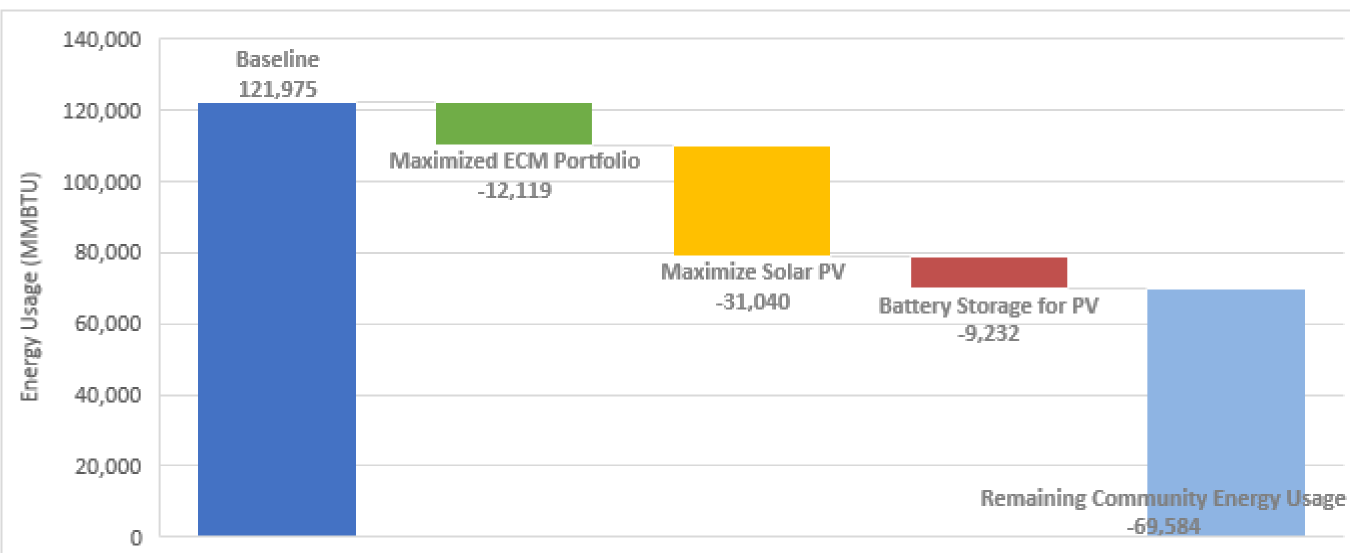
The total ECM retrofit cost is about $1.84 M due to the application of the maximum ECM strategy listed later in the appendix. The ECMs applied to the community are: (1) whole community interior LED retrofit; (2) C&I PPL retrofit; and, (3) residential DHW upgrade. This ECM strategy generates about a 9.9 percent reduction in the overall community energy usage – this corresponds to $446,300 in cost savings per year. Under this case, the reduction in community electric energy use is 81 percent and the reduction in natural gas use is 4 percent. This translates to a 43 percent reduction in the total community energy use. The energy usage of the community was shown to be decreased by 52,391 MMBTU from the baseline to a final community energy use of 69,584 MMBTU. Standing alone, the simple payback for applying only the ECMs is about 4 years. The total solar capacity is 6.0 MW and the total battery capacity is 2.8 MW. These capacities were established through an analysis of the maximum capacity of the Oak View community grid for DER technologies. The simple payback of the whole project is 8.7 years.

Table B-1: Case A Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
Maximized ECM Portfolio	12,119	-9.9%	1,874,471	6.5	446,300	4.2
Maximize Solar PV (6.0 MW)	31,040	-25.4%	15,900,000	2.0	1,364,600	11.7
Battery Storage for PV (2.8 MW)	9,232	-7.6%	1,400,000	6.6	405,828	3.5
Baseline	121,975					
Total Energy Savings	-52,391	-43.0%				
Case Energy Usage	69,584		19,174,471	2.7	2,216,728	8.7

Source: Altura Associates

Figure B-1: Case A Community Energy Usage Breakdown



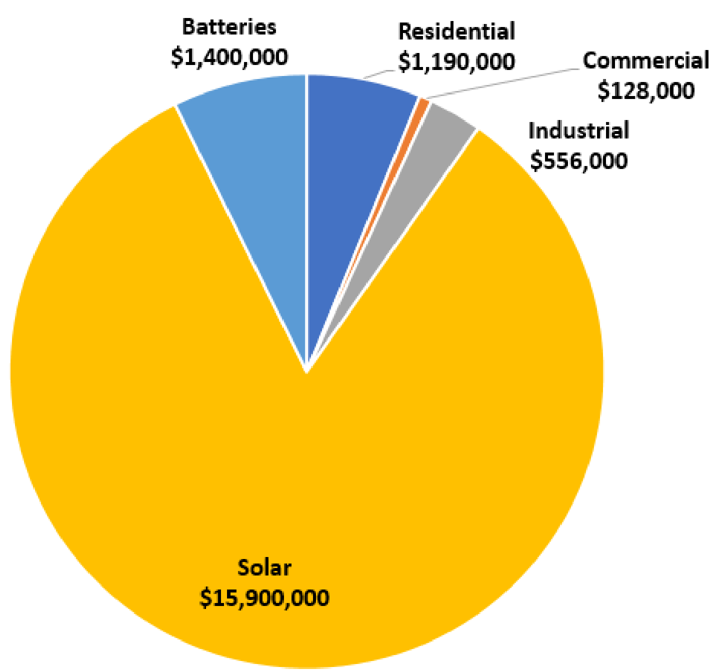
Source: Altura Associates

Table B-2: Case A Community Energy Usage Breakdown by Energy Source

	Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,974	N/A	17,987	N/A	605,982	N/A
Maximized ECM Portfolio	-12,119	-9.9%	-2,829	-15.7%	-24,381	-4.0%
Maximize Solar PV	-31,040	-25.4%	-9,097	-50.6%	0	0.0%
Battery Storage for PV	-9,232	-7.6%	-2,705	-15.0%	0	0.0%
Final Community Energy Usage	**69,584**	**-43.0%**	**3,356**	**-81.3%**	**581,600**	**-4.0%**

Source: Altura Associates

Figure B-2: Case A Cost Breakdown



Source: Altura Associates

Case B: Maximize ECMs / Maximize Solar PV / Battery Storage and EVs – No Budget Constraints

Case B mimics Case A exactly, except for the addition of EV charging stations which provides infrastructure that would allow the community to engage in charging their electric vehicles or ride-sharing programs. The key difference between Case B and Case A is that due to the added cost of the EV charging stations, the simple payback is not as beneficial as could be hoped for and was shown in Case A. The Case B scope assessment and the Case B cost breakdown are shown below. The solar and battery capacity is unchanged from Case A. The amount of EV charging which is assumed for Case B is one fast charging station and four Level II charging stations (additional information on the EV charging stations can be found in the analysis for community-level solar and battery storage.

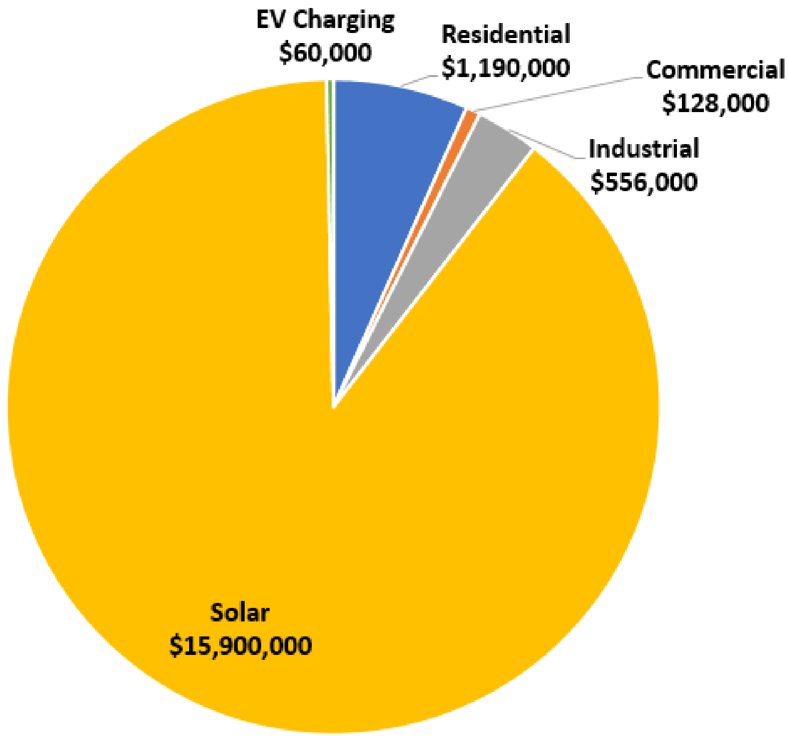
For Case B, the final annual community energy use is 69,584 MMBTU/year. The total project cost is around $19.2 M and the simple payback is around 8.7 years. The project specifications are only marginally different from Case A. Further details regarding the elements of Case B can be found below. The "Community Energy Usage Breakdown" and "Community Energy Usage Breakdown by Energy Source" are the same as in Case A.

Table B-3: Case B Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
Maximized ECM Portfolio	12,119	-9.9%	1,874,471	6.5	446,300	4.2
Maximize Solar PV (6.0MW)	31,040	-25.4%	15,900,000	2.0	1,364,600	11.7
Battery Storage for PV (2.8MW)	9,232	-7.6%	1,400,000	6.6	405,828	3.5
EV Capabilities	0	0.0%	60,000	N/A	N/A	N/A
Baseline	121,975					
Total Energy Savings	-52,391	-43.0%				
Case Energy Usage	69,584		19,234,471	2.7	2,216,728	8.7

Source: Altura Associates

Figure B-3: Case B Cost Breakdown



Source: Altura Associates

Case C: Maximize ECMs / Maximize Solar PV – No Budget Constraints

The major difference between Case C and Cases A and B is the elimination of battery technology from the case design. Without the battery storage enabled savings, this case becomes weaker than either case before with a lower simple payback of 9.8 years (compared to 8.7 years) and a lower efficacy (2.43 kBTU/$ vs. 2.7 kBTU/$). While project costs are lower, the total energy savings also is reduced (e.g. Case A has 43 percent community energy use reductions, while Case C only has 35 percent). This points to the likely need for batteries to be a part of the larger design.

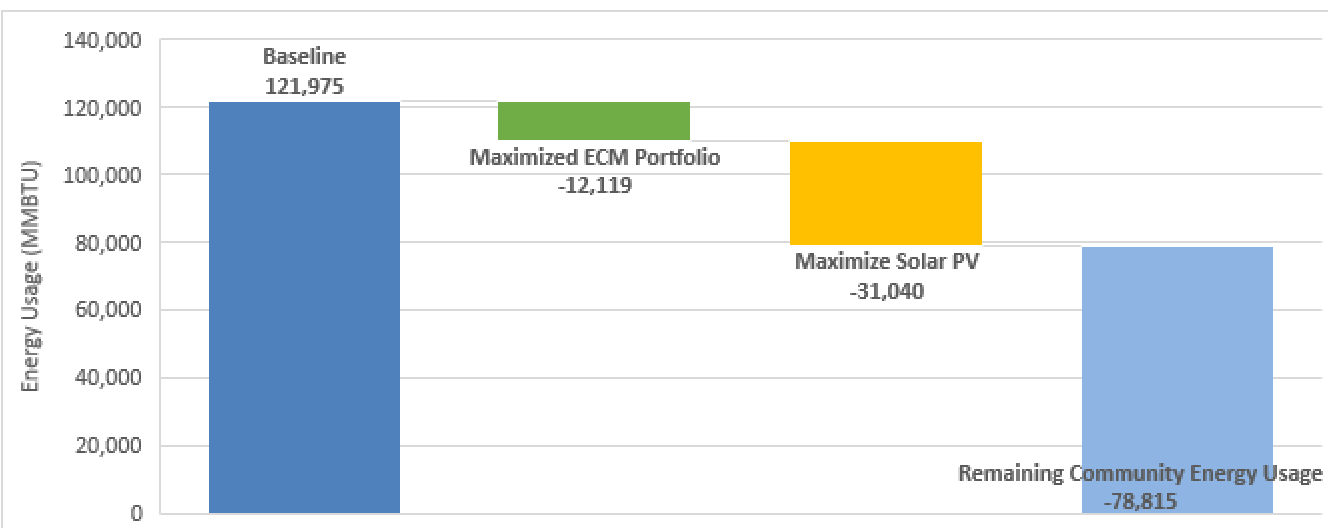
The final community energy use under Case C is 78,815 MMBTU/year, a reduction of 43,160 MMBTU/year (35 percent from baseline). This reduction is composed of a 66 percent reduction in community electricity use and a 4 percent reduction in community natural gas use. The annual energy cost savings are $1.8 M and the simple payback from the project is 9.8 years. In this case, 6.0 MW of solar capacity is assumed (similar to Case A and B).

Table B-4: Case C Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
Maximized ECM Portfolio	12,119	-9.9%	1,874,471	6.5	446,300	4.2
Maximize Solar PV (6.0 MW)	31,040	-25.4%	15,900,000	2.0	1,364,600	11.7
Baseline	121,975					
Total Energy Savings	-43,160	-35.4%				
Case Energy Usage	78,815		17,774,471	2.4	1,810,900	9.8

Source: Altura Associates

Figure B-4: Case C Community Energy Usage Breakdown



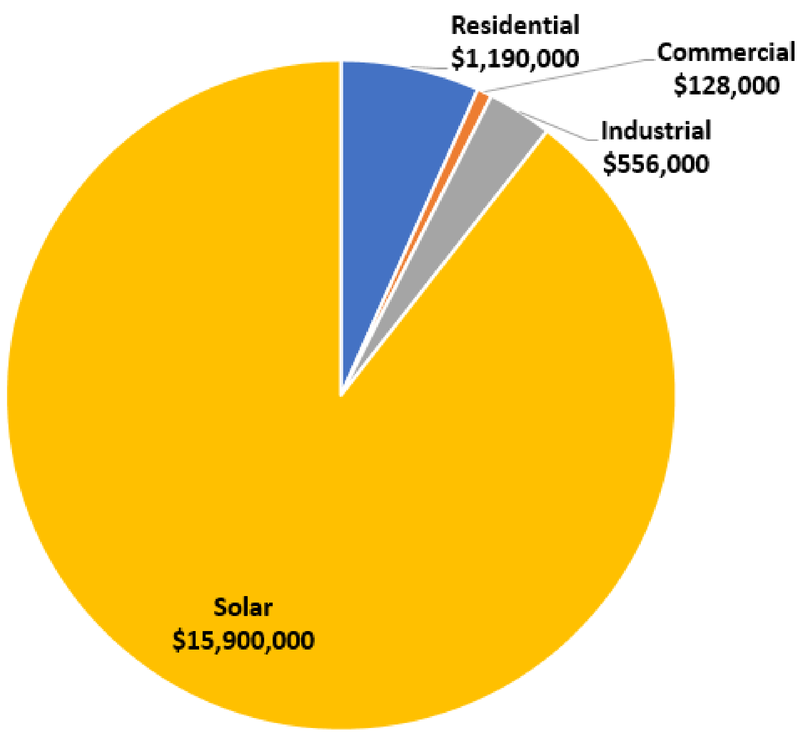
Source: Altura Associates

Table B-5: Case C Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
Maximized ECM Portfolio	-12,119	-9.9%	-2,829	-15.7%	-24,382	-4.0%
Maximize Solar PV	-31,040	-25.4%	-9,097	-50.6%	0.00	0.0%
Final Community Energy Usage	**78,815**	**-35.4%**	**6,062**	**-66.3%**	**581,601**	**-4.0%**

Source: Altura Associates

Figure B-5: Case C Cost Breakdown



Source: Altura Associates

Case D: Maximize Commercial and Industrial Solar PV – Budget Constrained

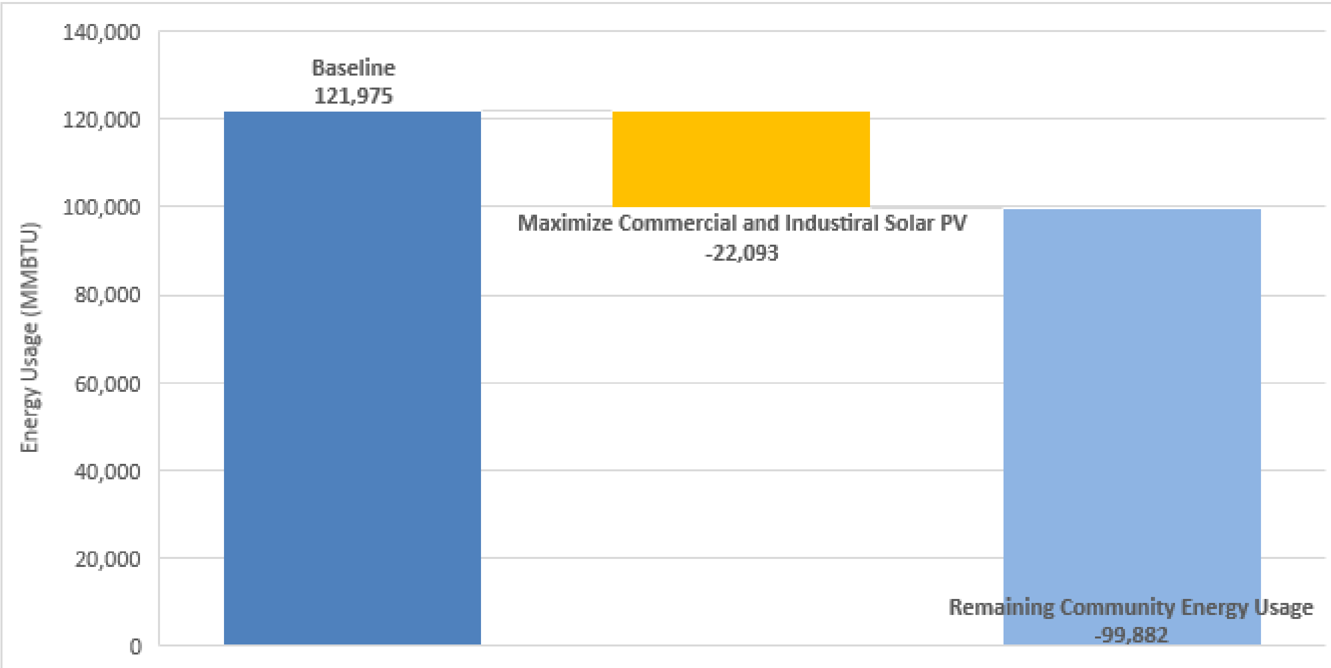
In Case D, the ability of the community's energy needs to be met solely with solar PV placed on commercial and industrial installations is identified. The total cost of Case D is $11.4 M and the community energy use is reduced by 18 percent (22,093 MMBTU/year). The total solar capacity that is available to the commercial and industrial sectors is 4.3 MW, which translates to 6,475 MWh in annual savings (36 percent of community electricity use). The annual energy cost savings provided by this case are $971,200 and simple payback of the case is 10.4 years.

Table B-6: Case D Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
Maximize Commercial and Industrial Solar PV (4.3 MW)	22,093	-18.1%	11,395,000	1.9	971,200	11.7
Baseline	121,975					
Total Energy Savings	-22,093	-18.1%				
Case Energy Usage	99,882		11,395,000	1.9	971,200	11.7

Source: Altura Associates

Figure B-6: Case D Community Energy Usage Breakdown



Source: Altura Associates

Table B-7: Case D Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Annual Electric Energy Savings (MWh)	Percent Reduction (%)	Annual Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
Maximize Commercial and Industrial Solar PV	-22,093	-18.1%	-6,475	-36.0%	0	0.0%
Final Community Energy Usage	99,882	-18.1%	11,513	-36.0%	605,983	0.0%

Source: Altura Associates

Case E: Maximize Residential Solar PV – Budget Constrained

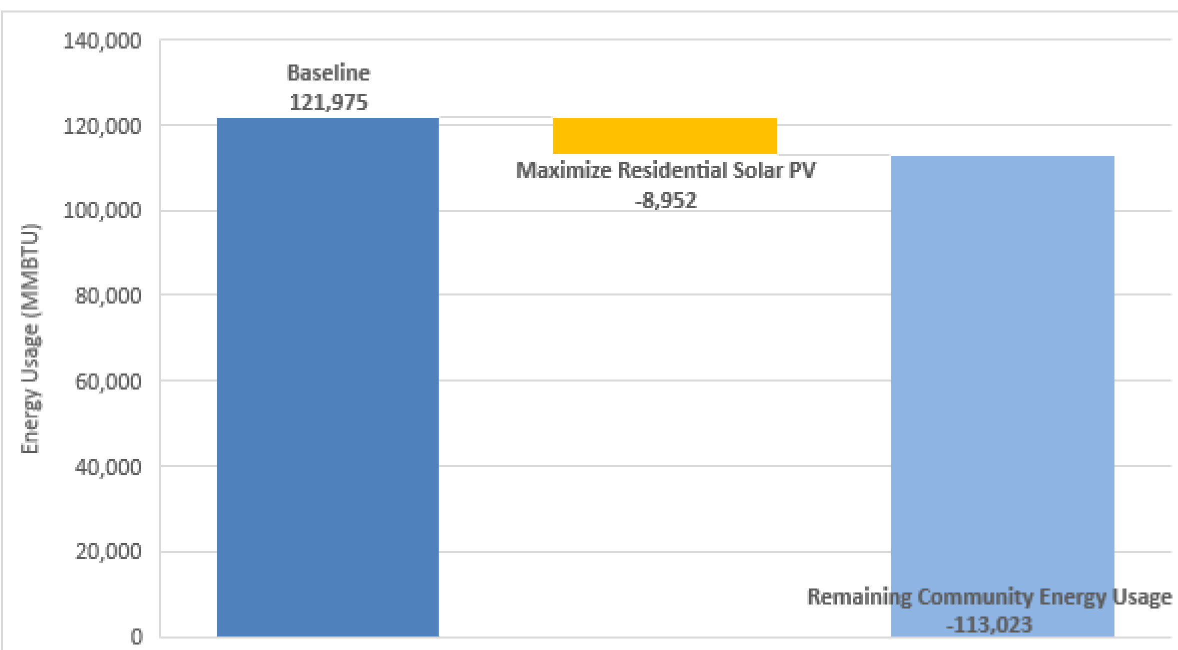
Case E complements Case D by showing the potential of solar in the residential sector, thus giving a full view of the community solar potential. The total residential solar capacity is 1.7 MW resulting in 2,624 MWh in annual energy savings. This translates into a reduction of community electricity usage of 15 percent and the community energy savings of 8,952 MMBTU/year (about 7 percent of the community energy use) with no savings associated with natural gas use. This cost of applying solar PV to residential buildings is $4.3 M, far less than the total budget allocation and the simple payback with this case is 10.8 years. The table and figure below display the main elements of the case.

Table B-8: Case E Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
Maximize Residential Solar PV (1.7 MW)	8,952	-7.3%	4,250,000	2.1	393,500	10.8
Baseline	121,975					
Total Energy Savings	-8,952	-7.3%				
Case Energy Usage	113,023		4,250,000	2.1	393,500	10.8

Source: Altura Associates

Figure B-7: Case E Community Energy Usage Breakdown



Source: Altura Associates

Table B-9: Case E Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
Maximize Residential Solar PV	-8,952	-7.3%	-2,624	-14.6%	0	0.0%
Final Community Energy Usage	113,023	-7.3%	15,364	-14.6%	605,983	0.0%

Source: Altura Associates

Case F: Maximize ECMs / Maximize Rooftop Solar PV – Budget Constrained

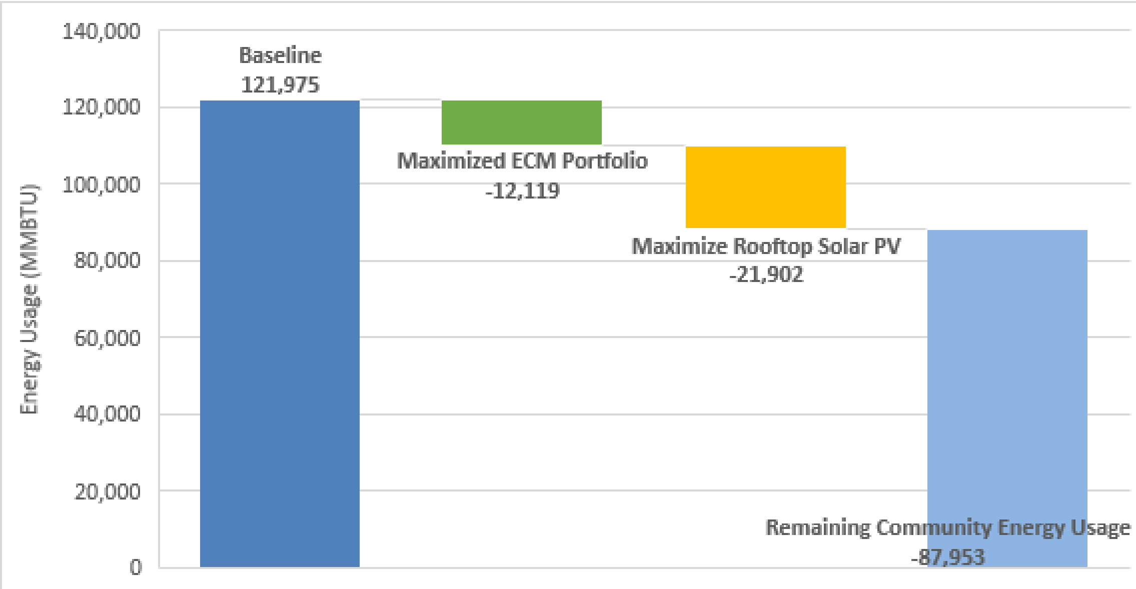
Case F serves to explore when the optimal maximized ECM is applied and using the remaining project budget to maximize the rooftop solar applied to the community. Case D uses the full project budge of $16 M and generates energy cost savings of $1.4 M per year. The simple payback of the project is 11.4 years and the total energy reduction from the baseline is 34,021 MMBTU/year or 28 percent. Through the applied ECMs and rooftop solar installations, the community electricity use is reduced 51 percent and natural gas energy use is lowered 4 percent. The total solar capacity of Case F is 4.2 MW, yielding a reduction in community electricity use of 6,419 MWh annually.

Table B-10: Case F Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
Maximized ECM Portfolio	12,119	-9.9%	1,874,471	6.5	446,300	4.2
Maximize Rooftop Solar PV (4.2MW)	21,902	-18.0%	14,125,529	1.6	962,800	14.7
Baseline	121,975					
Total Energy Savings	-34,021	-27.9%				
Case Energy Usage	87,953		16,000,000	2.1	1,409,100	11.4

Source: Altura Associates

Figure B-8: Case F Community Energy Usage Breakdown



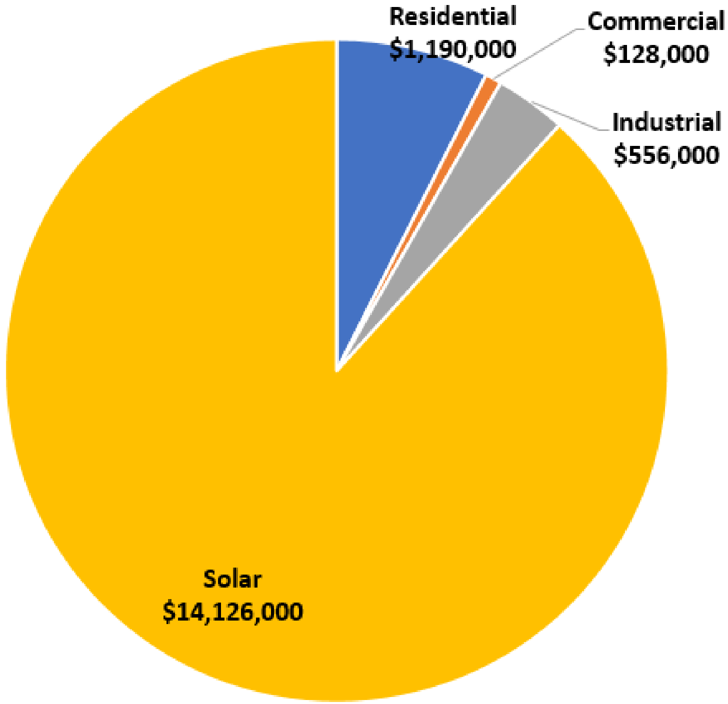
Source: Altura Associates

Table B-11: Case F Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
Maximized ECM Portfolio	-12,119	-9.9%	-2,829	-15.7%	-24,382	-4.0%
Maximize Rooftop Solar PV	-21,902	-18.0%	-6,419	-35.7%	0.00	0.0%
Final Community Energy Usage	87,954	-27.9%	8,740	-51.4%	581,601	-4.0%

Source: Altura Associates

Figure B-9: Case F Cost Breakdown



Source: Altura Associates

Case G: Apply Rooftop and Canopy Solar PV – Budget Constrained

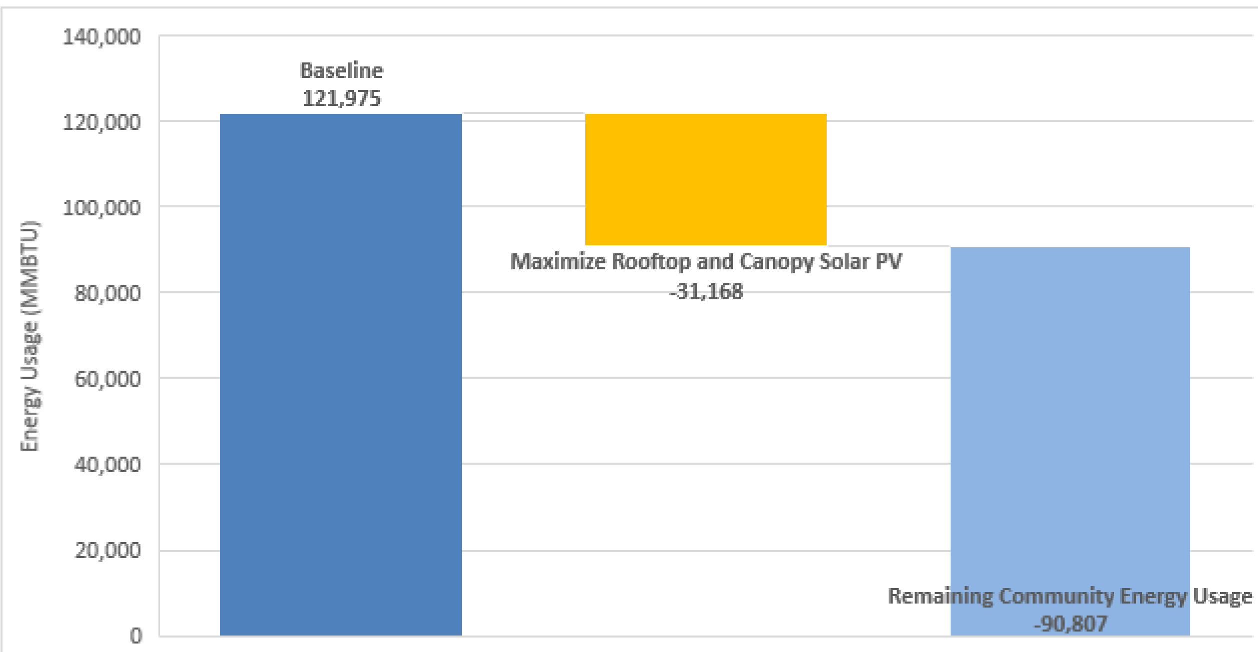
Case G aims to assess the full solar capacity of the community under the $16 M available budget constraint. The total solar capacity established in this case is 6.0 MW, resulting in a reduction of the community electrical energy use of 9,134 MWh annually. These energy savings translate to a 51 percent reduction in electric energy use and 26 percent reduction in total community energy use (31,168 MMBTU/year). Further breakdowns of Case G follow.

Table B-12: Case G Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
Maximize Rooftop and Canopy Solar PV (6.0MW)	31,168	-25.6%	16,000,000	2.0	1,370,200	11.7
Baseline	121,975					
Total Energy Savings	-31,168	-25.6%				
Case Energy Usage	90,807		16,000,000	2.0	1,370,200	11.7

Source: Altura Associates

Figure B-10: Case G Community Energy Usage Breakdown



Source: Altura Associates

Table B-13: Case G Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
Maximize Rooftop and Canopy Solar PV	-31,168	-25.6%	-9,134	-50.8%	0	0.0%
Final Community Energy Usage	90,807	-25.6%	8,854	-50.8%	605,983	0.0%

Source: Altura Associates

Case H: Apply All ECMs – Budget Constrained

In Case H, the entirety of the ECMs are applied to the community to evaluate the full energy savings potential of the ECMs within the budget constraints. ECMs that yield increases in sector energy use, such as residential cool roof and commercial DHW upgrades, were eliminated from the case community design. The ECMs that composed Case H are: community-wide – interior and exterior LED replacements, PPL retrofits (residential appliances and C&I plug and process loads) and insulation upgrades; residential and industrial DHW improvements; and, commercial and industrial additions of cool roof technologies.

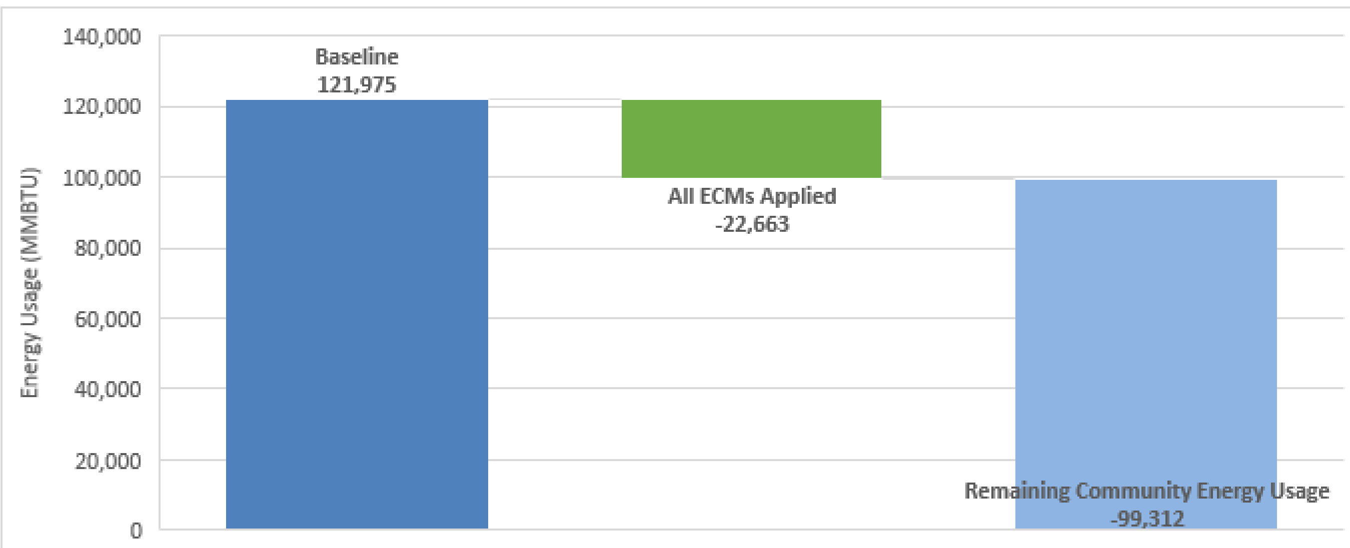
The total energy reductions from the community's baseline energy use is 22,663 MMBTUs. This corresponds to a 19 percent reduction in community energy use – 20 percent reduction of electrical energy and 18 percent reduction in natural gas use. The total cost of applying all ECMs is $10.8 M and has a simple payback of 17.34 years. When Case H is compared to the "maximized ECM" cases presented earlier, the benefits of excluding some ECMs from the community design can be seen. While Case H has a simple payback of 17.34 years, the simple payback of only applying the maximized ECM case is 4.2 years. Additionally, the energy reductions per dollar of applying all ECMs is 2.1 kBTU/$ for Case D, while the maximized cases have a value of 6.5 kBTU/$. Additionally, comparing the cases in regards to pure energy savings, the maximized ECM case is able to achieve over half the savings (12,119 MMBTU/year) for about one-fifth of the cost ($1.9 M).

Table B-14: Case H Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
All ECMs Applied	22,663	-18.6%	10,793,052	2.1	622,500	17.3
Baseline	121,975					
Total Energy Savings	-22,663	-18.6%				
Case Energy Usage	99,312		10,793,052	2.1	622,500	17.3

Source: Altura Associates

Figure B-11: Case H Community Energy Usage Breakdown



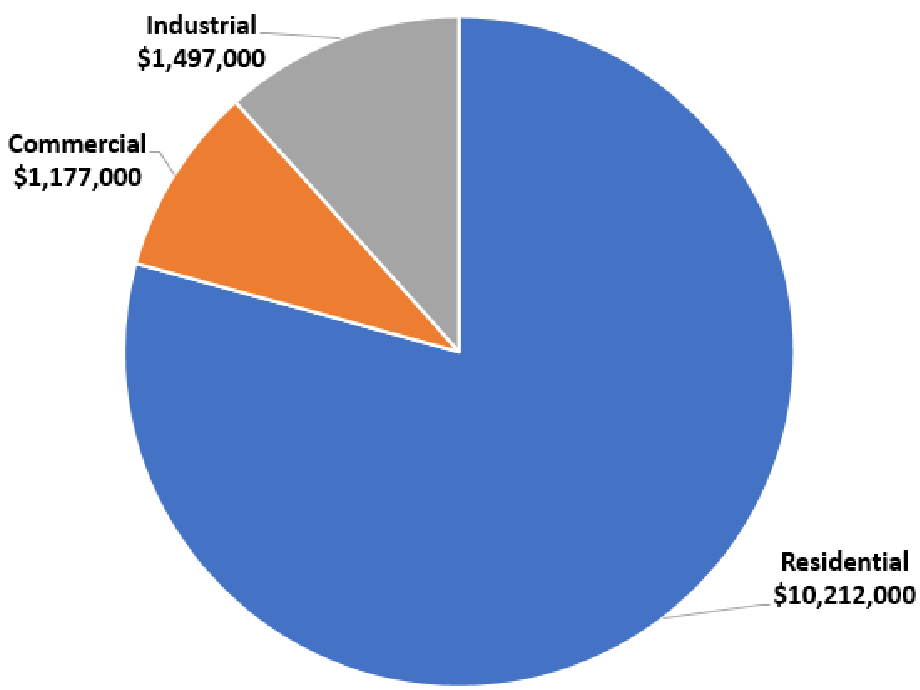
Source: Altura Associates

Table B-15: Case H Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
All ECMs Applied	-22,663	-18.6%	-3,509	-19.5%	-106,906	-17.6%
Final Community Energy Usage	99,312	-18.6%	14,479	-19.5%	499,077	-17.6%

Source: Altura Associates

Figure B-12: Case H Cost Breakdown



Source: Altura Associates

Case I: LED Lighting / Canopy Solar PV – Budget Constrained

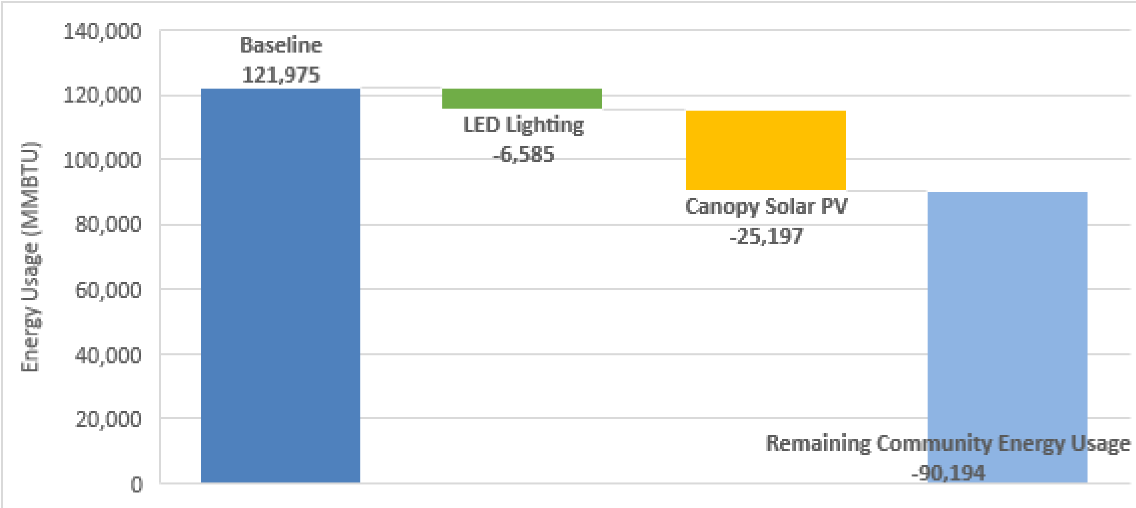
Case I examines applying a different subset of ECMs in the community rather than applying the maximized ECM portfolio or applying all ECMs. The total expenditure of Case I is the project cap of $16 M and the only scope items within the case are an interior and exterior LED lighting retrofit applied across all sectors and canopy solar. The total cost of implementing LEDs across the community is $1.35 M with the remainder of the projected budget used for canopy solar. The total energy savings simulated by the case is a 31,781 MMBTU/year reduction from the baseline (26 percent). The majority of this reduction was due to the 4.9 MW of solar implemented within the community. The total energy savings generated from Case I are about $1.4 M, resulting in a simple payback period of 11.3 years. Under this case, the community electrical usage would decrease 53 percent and the natural gas usage would stay consistent with the baseline (increase of 1 percent). As stated previously, the increase in community natural gas use is attributed to the increase in natural gas heating needed with the reduction of "waste heat" expelled from inefficient products.

Table B-16: Case I Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
LED Lighting	6,585	-5.4%	1,357,020	4.9	309,100	4.4
Canopy Solar PV (4.9MW)	25,197	-20.7%	14,642,980	1.7	1,107,700	13.2
Baseline	121,975					
Total Energy Savings	-31,781	-26.1%				
Case Energy Usage	90,194		16,000,000	2.0	1,416,800	11.3

Source: Altura Associates

Figure B-13: Case I Community Energy Usage Breakdown



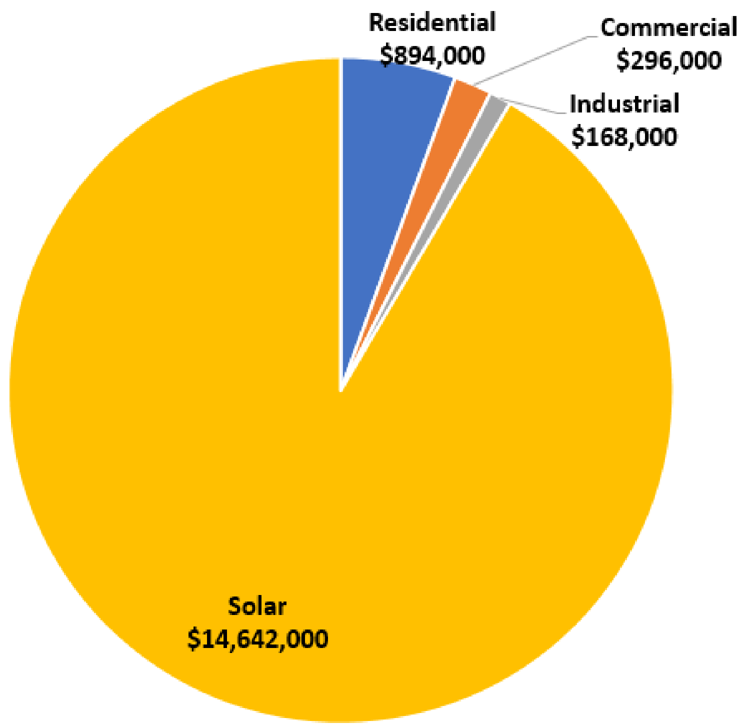
Source: Altura Associates

Table B-17: Case I Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
LED Lighting	-6,585	-5.4%	-2,105	-11.7%	7,495	1.2%
Canopy Solar PV	-25,197	-20.7%	-7,384	-41.1%	0	0.0%
Final Community Energy Usage	90,193	-26.1%	8,499	-52.8%	613,478	1.2%

Source: Altura Associates

Figure B-1462: Case I Cost Breakdown



Source: Altura Associates

Case J: LED Lighting / Rooftop Solar PV – Budget Constrained

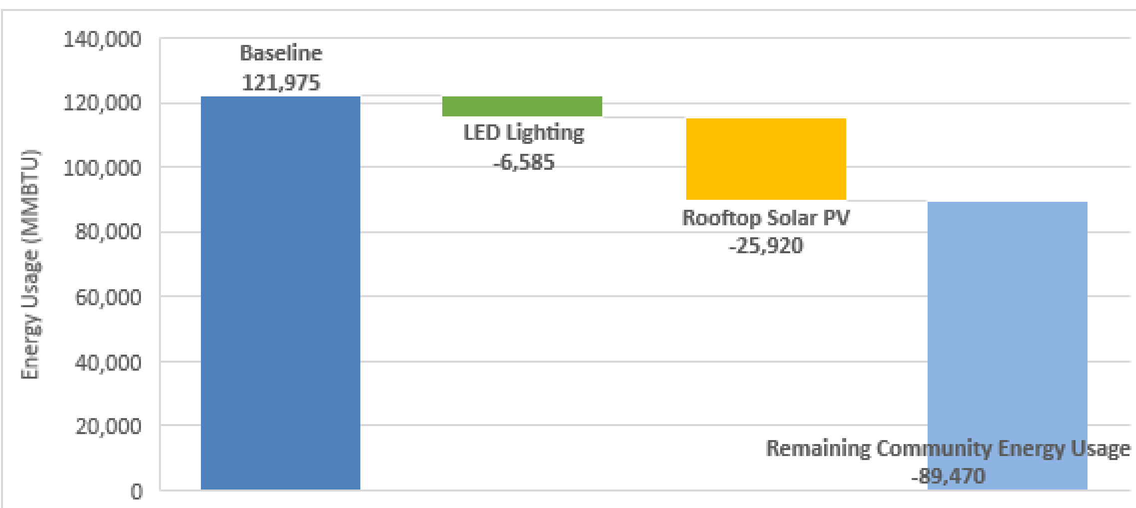
Case J can most closely be compared to Case I – the cases serve to show the different energy savings available to applying canopy solar across the community vs. rooftop solar. For Case J, the final projected cost is $13.9 M and the energy cost savings are $1.4 M annually, yielding a simple payback period of 9.6 years. Applying the ECMs and DER measures described in Case J show a 27 percent reduction in total community energy use (32,505 MMBTU/year). This reduction can be further broken down into a 54 percent reduction in community electricity use and a slight increase in community natural gas use (increase of 1 percent). The total solar capacity is found to be 4.2 MW. Comparing Cases I and J show that implementing rooftop solar first before canopy solar yields a greater cost efficiency – rooftop solar has an efficacy of 2.1 kBTU/$ while canopy solar has an efficacy of 1.7 kBTU/$. Additionally, the case shows the limits of rooftop solar availability. Given these limitations, the final design may want to employ rooftop solar supplemented by canopy solar. Further details of the case study are found further in this section. The Case I cost breakdown is the same as that of Case J.

Table B-1845: Case J Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
LED Lighting	6,585	-5.4%	1,357,020	4.9	309,100	4.4
Rooftop Solar PV (4.2MW)	25,920	-21.3%	12,500,000	2.1	1,139,500	11.0
Baseline	121,975					
Total Energy Savings	-32,505	-26.6%				
Case Energy Usage	89,470		13,857,019.99	2.35	1,448,600.00	9.57

Source: Altura Associates

Figure B-15: Case J Community Energy Usage Breakdown



Source: Altura Associates

Table B-19: Case J Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
LED Lighting	-6,585	-5.4%	-2,105	-11.7%	7,495	1.2%
Rooftop Solar PV	-25,920	-21.3%	-7,596	-42.2%	0	0.0%
Final Community Energy Usage	89,470	-26.6%	8,287	-53.9%	613,478	1.2%

Source: Altura Associates

Case K: LED Lighting / Residential Appliances and Plug load / Canopy Solar PV – Budget Constrained

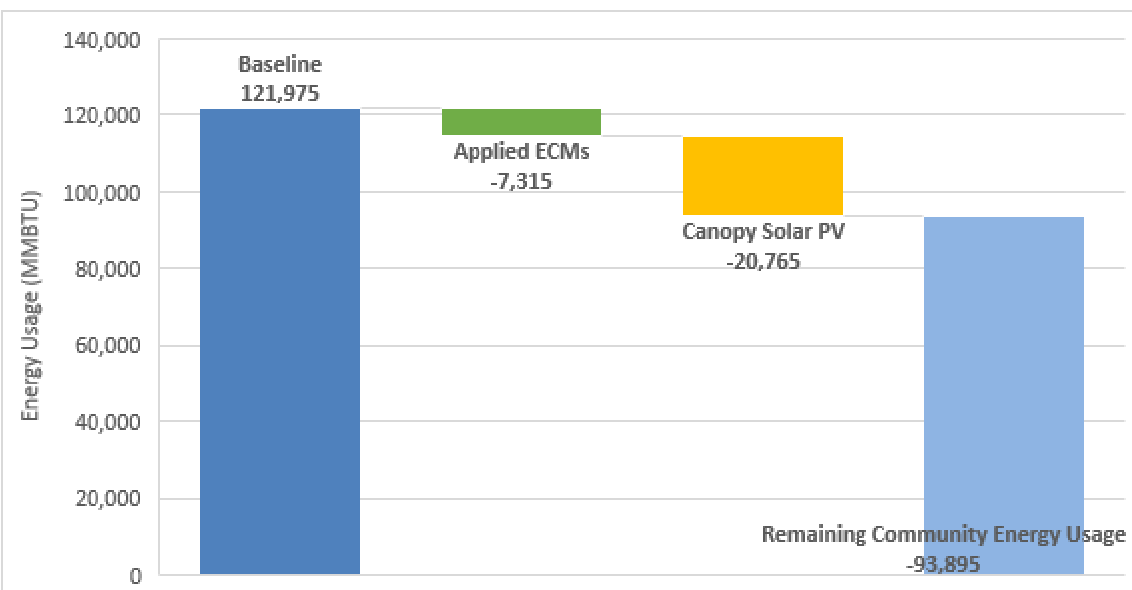
Case K expands on Case I by adding residential appliance retrofit to the LED lighting measure to generate more savings through applied ECMs. The total energy savings found through Case K is 28,080 MMBTU/year (23 percent) – a reduction of 47 percent of the community's electricity use. Similar to Case I, the natural gas use of the community increase negligibly (1 percent). The total cost of applying Case K is $16 M with energy cost savings totaling $1.3 M annually, yielding a simple payback period of 13 years. Comparing Case K and Case I, the project efficacy is higher for Case I (1.99 kBTU/$) than Case K (1.75 kBTU/$). This indicates that in constructing the final community design, it will be more effective to install canopy solar over performing a residential appliance and plug load retrofit. The total solar capacity installed in Case K is 4.0 MW which generates 6,085 MWh of annual community electricity savings.

Table B-20: Case K Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
LED Lighting, Residential Appliances and Plug load	7,315	-6.0%	3,932,719	1.9	337,900	11.6
Canopy Solar PV (4.0MW)	20,765	-17.0%	12,067,281	1.7	912,800	13.2
Baseline	121,975					
Total Energy Savings	-28,080	-23.0%				
Case Energy Usage	93,895		16,000,000	1.8	1,250,700	12.8

Source: Altura Associates

Figure B-16: Case K Community Energy Usage Breakdown



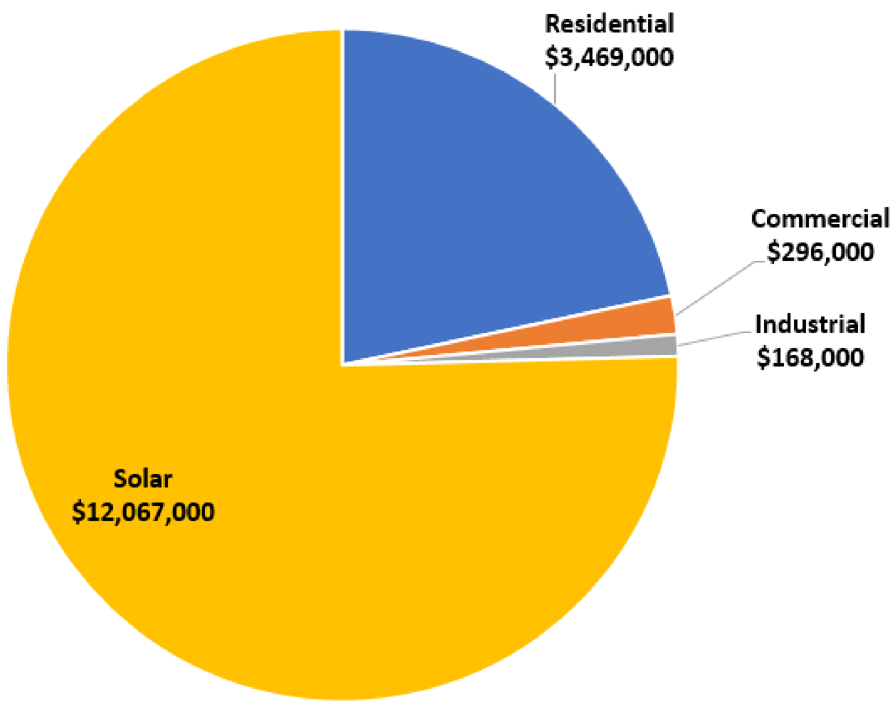
Source: Altura Associates

Table B-21: Case K Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
LED Lighting, Residential Appliances and Plug load	-7,315	-6.0%	-2,310	-12.8%	9,560	1.6%
Canopy Solar PV	-20,765	-17.0%	-6,085	-33.8%	0	0.0%
Final Community Energy Usage	93,895	-23.0%	9,593	-46.7%	615,543	1.6%

Source: Altura Associates

Figure B-17: Case K Cost Breakdown



Source: Altura Associates

Case L: LED Lighting / Residential Appliances and Plug load / Residential Building Envelope Retrofit / Canopy Solar PV – Budget Constrained

The total energy savings produced from applying Case L is 29,719 MMBTU/year, 25 percent of the total community energy use. These savings consist of a 37 percent reduction in electric energy use and a 12 percent reduction in natural gas use. The energy cost savings provided by Case L are $1.1 M annually. With the cost of the project at the project cap of $16 M, the simple payback period is 15 years. In this case, canopy solar is applied within the community. The total solar capacity is 2.9 MW, which translates into 4,327 MWh of energy reduced annually.

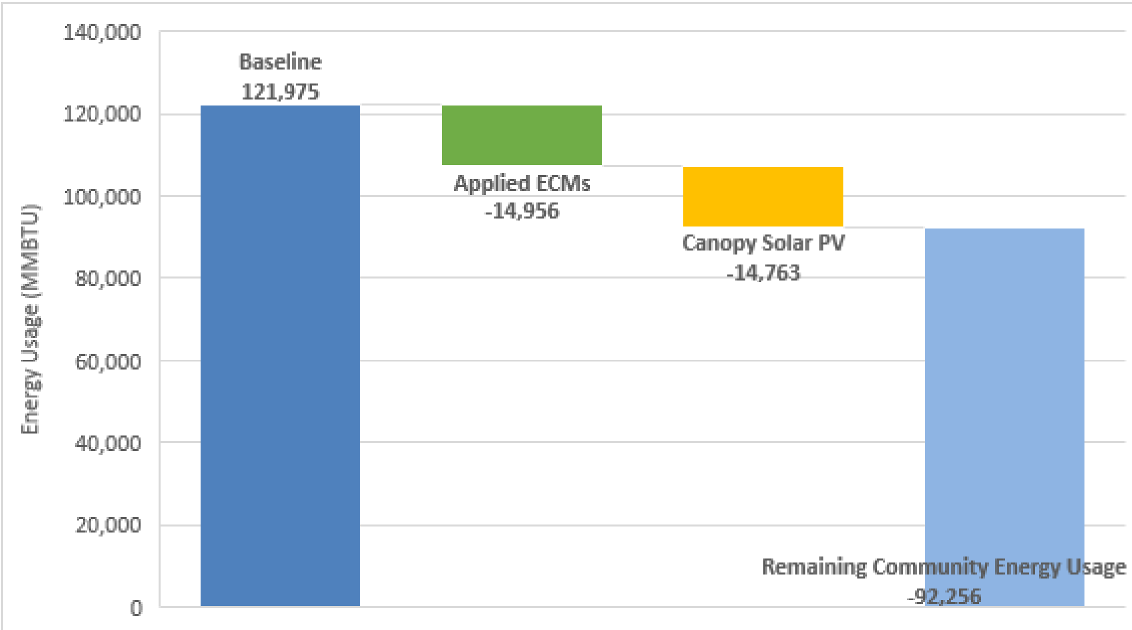
Comparing Cases J, K and L on an energy reduction per project dollar basis (1.99 kBTU/$, 1.75 kBTU/$ and 1.86 kBTU/$ respectively), Case J still leads to the highest community energy reduction. However, Case L generates higher savings that Case K, indicating the engaging in the building envelope retrofit over the residential appliance and plug load retrofit would be most beneficial to the final design.

Table B-22: Case L Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
LED Lighting, Residential Appliances/ Plug load and Building Envelope Retrofit	14,956	-12.3%	7,420,683	2.0	417,700	17.8
Canopy Solar PV (2.9MW)	14,763	-12.1%	8,579,317	1.7	649,000	13.2
Baseline	121,975					
Total Energy Savings	-29,719	-24.4%				
Case Energy Usage	92,256		16,000,000	1.9	1,066,700	15.0

Source: Altura Associates

Figure B-18: Case L Community Energy Usage Breakdown



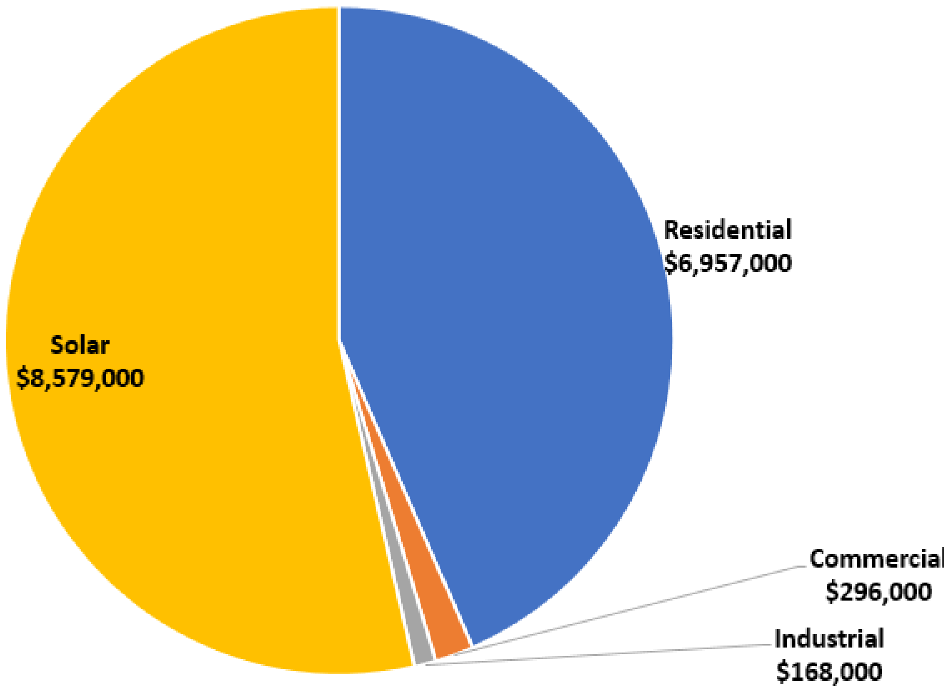
Source: Altura Associates

Table B-23: Case L Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
LED Lighting, Residential Appliances/ Plug load and Envelope Retrofit	-14,956	-12.3%	-2,360	-13.1%	-70,824	-11.7%
Canopy Solar PV	-14,763	-12.1%	-4,327	-24.1%	0	0.0%
Final Community Energy Usage	92,256	-24.4%	11,301	-37.2%	535,159	-11.7%

Source: Altura Associates

Figure B-19: Case L Cost Breakdown



Source: Altura Associates

Case M: LED Lighting / Residential Appliance and Plug load / Residential DHW / Canopy Solar PV – Budget Constrained

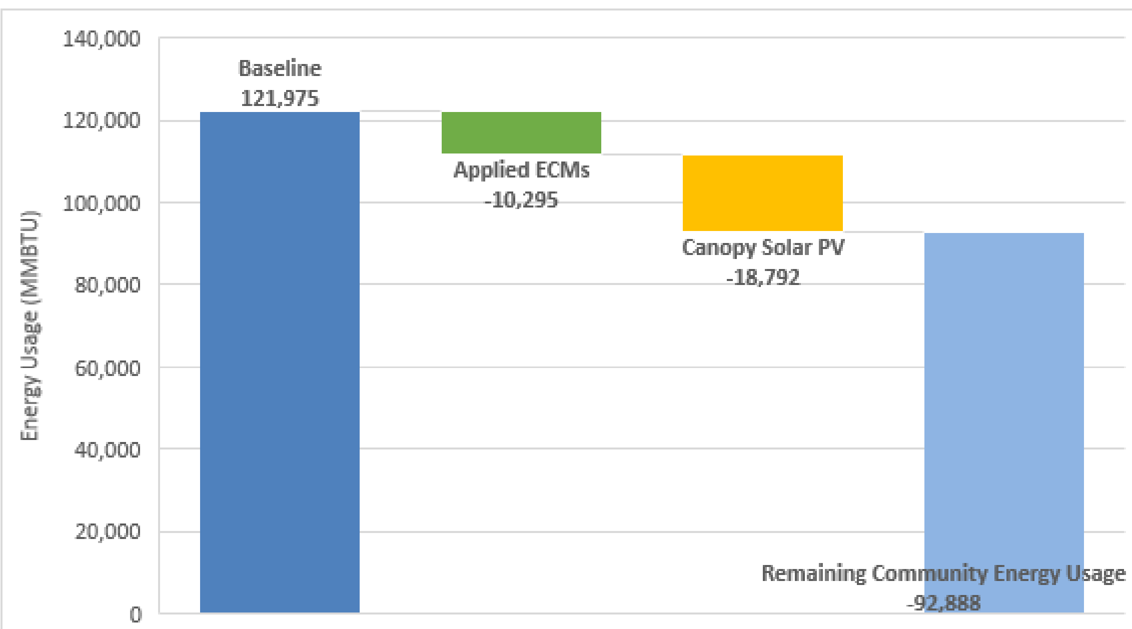
Case M replaces the residential envelop retrofit with a domestic hot water retrofit. The total projected cost is the project cap of $16 M. The energy savings generated is 29,070 MMBTU/year or a 24 percent reduction from the baseline. The 3.6 MW canopy solar array makes up a majority of the savings. Through Case M, the total community electricity use is estimated to be lowered by 43.5 percent and the total natural gas use is reduced by 4 percent. Compared to Case L, the natural gas savings are less – showing that the envelope retrofit reduces the natural gas expenditure of the community better than the domestic hot water upgrade. However, the cost efficiency of applying both ECM cases is comparable (around 2.03 kBTU/$) indicating that while there is a greater amount of potential savings under an envelope retrofit, the savings and cost for both cases scale similarly. The simple payback period of Case M is 14 years. Additional cost and savings information is tabulated below.

Table B-24: Case M Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
LED Lighting, Residential Appliances and DHW Retrofit	10,295	-8.4%	5,079,145	2.0	368,200	13.8
Canopy Solar PV (3.6 MW)	18,792	-15.4%	10,920,855	1.7	826,100	13.2
Baseline	121,975					
Total Energy Savings	-29,087	-23.8%				
Case Energy Usage	92,888		16,000,000	1.8	1,194,300	13.4

Source: Altura Associates

Figure B-20: Case M Community Energy Usage Breakdown



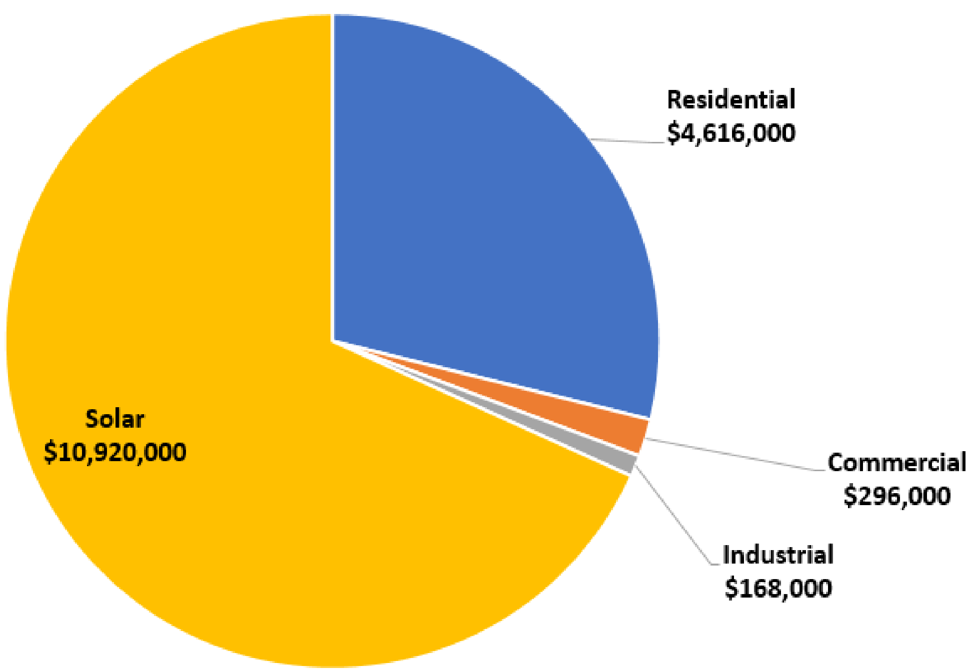
Source: Altura Associates

Table B-25: Case M Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
LED Lighting, Residential Appliances and DHW Retrofit	-10,295	-8.4%	-2,321	-12.9%	-22,222	-3.7%
Canopy Solar PV	-18,792	-15.4%	-5,507	-30.6%	0	0.0%
Final Community Energy Usage	92,888	-23.8%	10,160	-43.5%	583,761	-3.7%

Source: Altura Associates

Figure B-21: Case M Cost Breakdown



Source: Altura Associates

Case N: LED Lighting / Commercial and Industrial PPL Retrofits / Canopy Solar PV – Budget Constrained

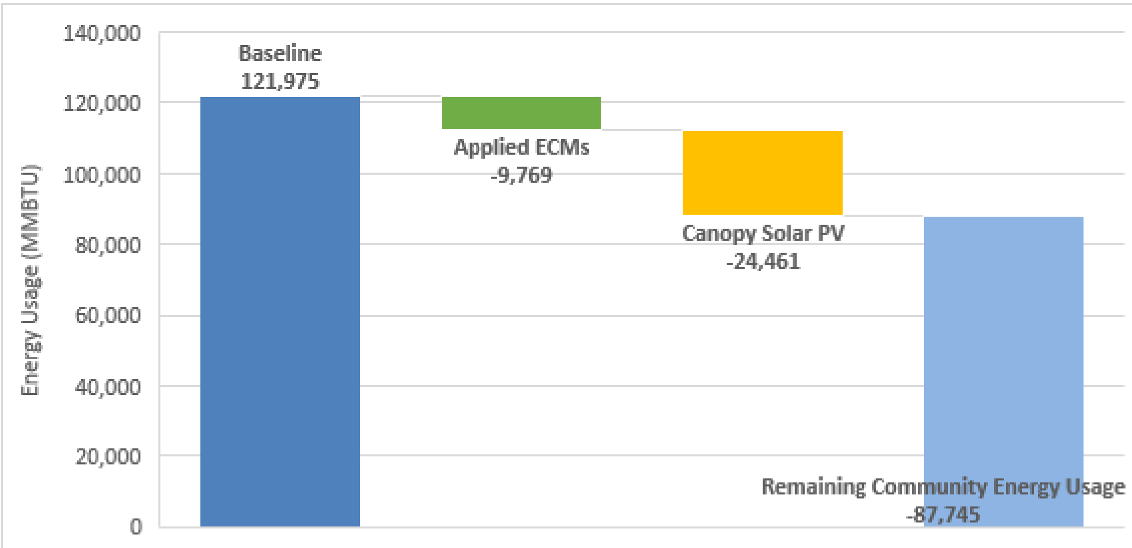
The total savings generated from Case N is 34,230 MMBTU/year, a reduction of 28 percent from the baseline. The total cost of Case N is $16 M. Case N incorporates a LED lighting retrofit across all sectors, a C&I plug and process load retrofit and canopy solar installations. The energy costs of the community are lowered by $1.5 M and the case has a simple payback period of the project is around 11 years. The project energy savings are only electric, where the electric use of the community drops by 57 percent (7,808 MWh). As with other projects that employ the LED retrofit, the natural gas usage of the community increases marginally (1 percent). The electric energy reductions are primarily caused by the installation of 4.7 MW of solar PV (7,169 MWh). Compared to the previous cases, this case is decently favorable, with a high energy reduction per dollar of 2.14 kBTU/$.

Table B-2646: Case N Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
LED Lighting, C&I PPL Retrofit	9,769	-8.0%	1,784,460	5.5	445,000	4.0
Canopy Solar PV (4.7MW)	24,461	-20.1%	14,215,540	1.7	1,075,300	13.2
Baseline	121,975					
Total Energy Savings	-34,230	-28.1%				
Case Energy Usage	87,745		16,000,000	2.1	1,520,300	10.5

Source: Altura Associates

Figure B-22: Case N Community Energy Usage Breakdown



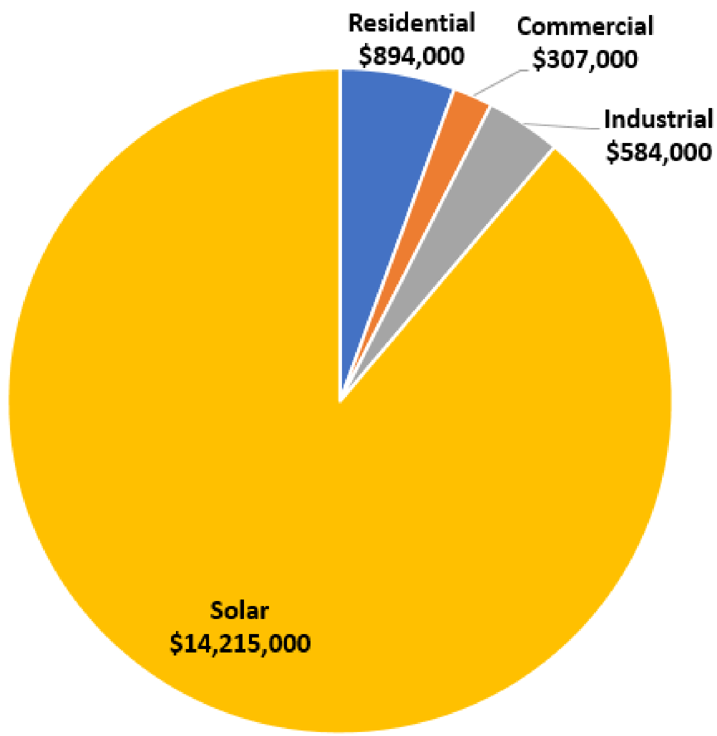
Source: Altura Associates

Table B-27: Case N Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
LED Lighting, C&I PPL Retrofit	-9,769	-8.0%	-3,011	-16.7%	7,290	1.2%
Canopy Solar PV	-24,461	-20.1%	-7,169	-39.9%	0	0.0%
Final Community Energy Usage	87,745	-28.1%	7,808	-56.6%	613,274	1.2%

Source: Altura Associates

Figure B-23: Case N Cost Breakdown



Source: Altura Associates

Case O: LED Lighting / Appliance and PPL Retrofits / Residential DHW Upgrade / Canopy Solar PV / Battery Storage for PV – Budget Constrained

Case O applies a full set of ECMs along with canopy solar PV and battery storage. Given the positive response observed for earlier cases where battery technologies were employed, the positive results of this case were expected. The set of ECMs applied to Case O consist of community-wide LED lighting retrofits and appliance and PPL retrofits. Additionally, this case included a DHW upgrade. The total energy savings of Case O are 30,515 MMBTU/year or 25 percent of the community's energy use. The savings can be broken down further – 46 percent of the electricity use and 4 percent of the natural gas use of the community is eliminated by this case. These reductions translate into $1.4 M in energy cost savings per year and a simple payback of around 11 years. The total projected cost is $16 M. In addition to the ECMs applied within the case, 3.3 MW of solar and 1.1 MW of battery storage are implemented. The combined DER technologies reduce the electric energy use of the community by 34 percent or 6 MWh annually.

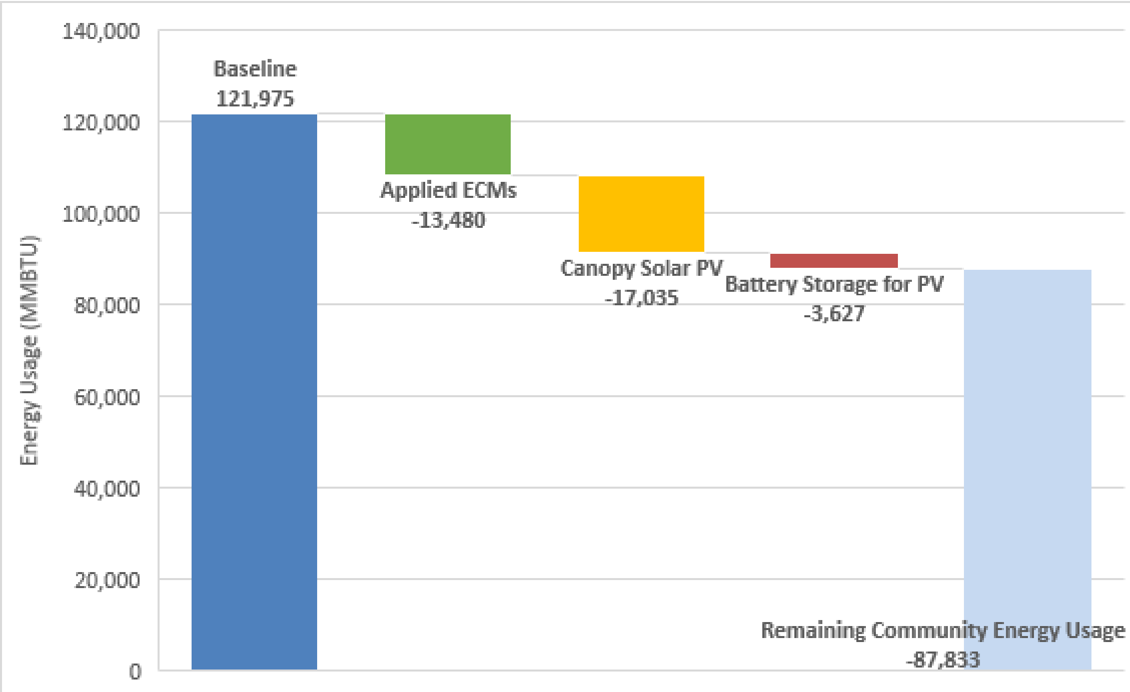
Compared to the other cases, Case O has a higher energy reduction to cost ratio (2.13 kBTU/$) and makes use of advanced DER making it a competitive case overall.

Table B-28: Case O Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
LED Lighting, Residential Appliances and PPL Retrofit, Residential DHW Retrofit	13,480	-11.1%	5,506,585	2.5	504,200	10.9
Canopy Solar PV (3.3 MW)	17,035	-14.0%	9,900,000	1.7	748,900	13.2
Battery Storage for PV (1.1 MW)	3,627	-3.0%	593,415	6.1	159,432	3.7
Baseline	121,975					
Total Energy Savings	-34,142	-28.0%				
Case Energy Usage	87,833		16,000,000	2.1	1,412,532	11.3

Source: Altura Associates

Figure B-24: Case O Community Energy Usage Breakdown



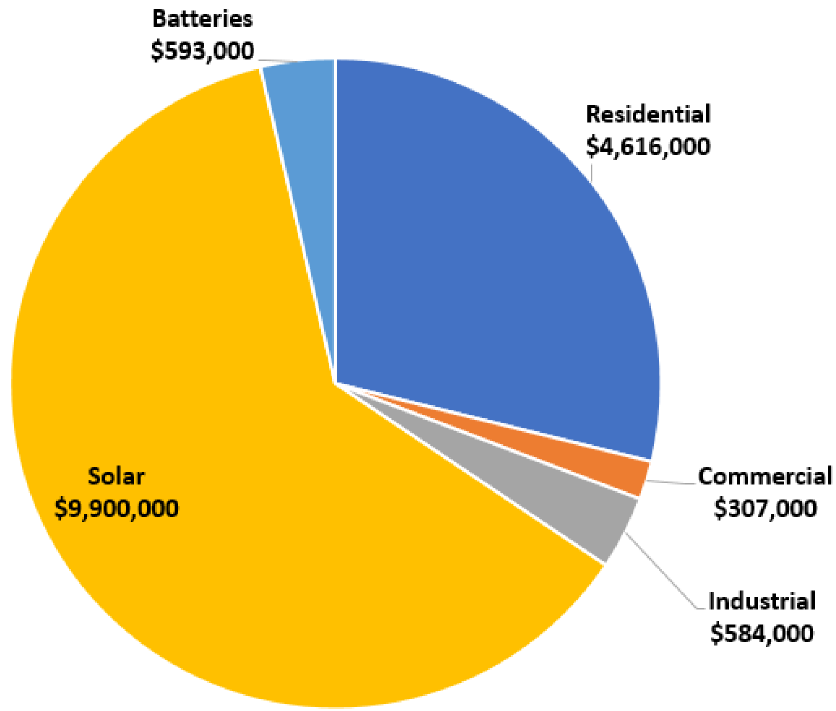
Source: Altura Associates

Table B-29: Case O Community Energy Usage Breakdown by Energy Source

	Annual Energy Savings (MMBTU)	Percent Reduction (%)	Electric Energy Savings (MWh)	Percent Reduction (%)	Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
LED Lighting, Residential Appliances and PPL Retrofit, Residential DHW Retrofit	-13,480	-11.1%	-3,226	-17.9%	-22,426	-3.7%
Canopy Solar PV	-17,035	-14.0%	-4,993	-27.8%	0	0.0%
Battery Storage for PV	-3,627	-3.0%	-1,063	-5.9%	0	0.0%
Final Community Energy Usage	87,833	-28.0%	8,706	-51.6%	583,556	-3.7%

Source: Altura Associates

Figure B-25: Case O Cost Breakdown



Source: Altura Associates

Case P: LED Lighting / Appliance and PPL Retrofits / Residential DHW Upgrade / Canopy Solar PV / EV Shared Use – Budget Constrained

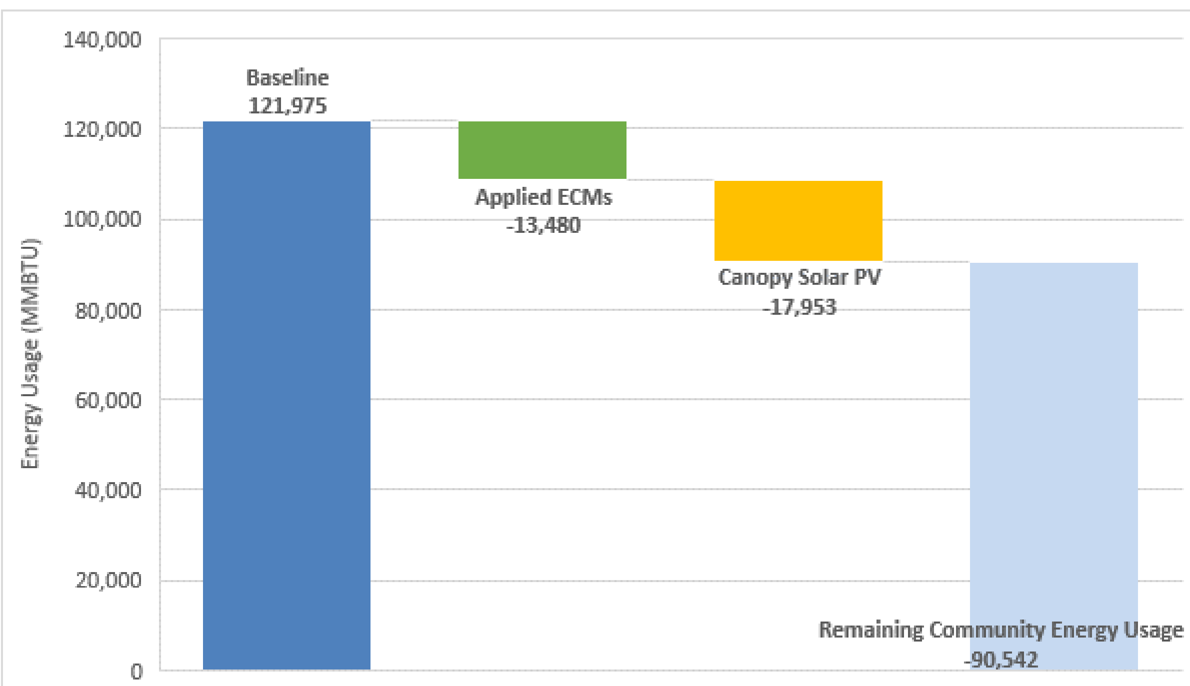
Case P serves to compare the savings with battery technologies by maintaining a similar mix of ECMs and DERs. The total cost of Case P is $16 M. The savings associated with the case is 31,433 MMBTU/year (26 percent) annually with the energy cost savings totaling $1.3 M. Implementing the EV capabilities and removing battery storage reduces the effectiveness and energy savings of the case when compared to Case O. The costs associated with the EV charging are linked to adding 1 DC fast charger and 4 Level II charging stations within the community. The total simple payback of the project is 12 years.

Table B-30: Case P Scope Item Assessment

Scope Item	Total Annual Energy Savings (MMBTU)	Percent Savings (%)	Item Cost ($)	Energy Reduced per Dollar Spent (kBTU/$)	Energy Cost Savings ($)	Simple Payback (years)
LED Lighting, Appliance and PPL Retrofit, and Residential DHW Retrofit	13,480	-11.1%	5,506,585	2.5	504,200	10.9
Canopy Solar PV (3.5MW)	17,953	-14.7%	10,433,415	1.7	789,200	13.2
EV Capabilities	0	0.0%	60,000	N/A	N/A	N/A
Baseline	121,975					
Total Energy Savings	-31,433	-25.8%				
Case Energy Usage	90,542		16,000,000	2.0	1,293,400	12.4

Source: Altura Associates

Figure B-26: Case P Community Energy Usage Breakdown



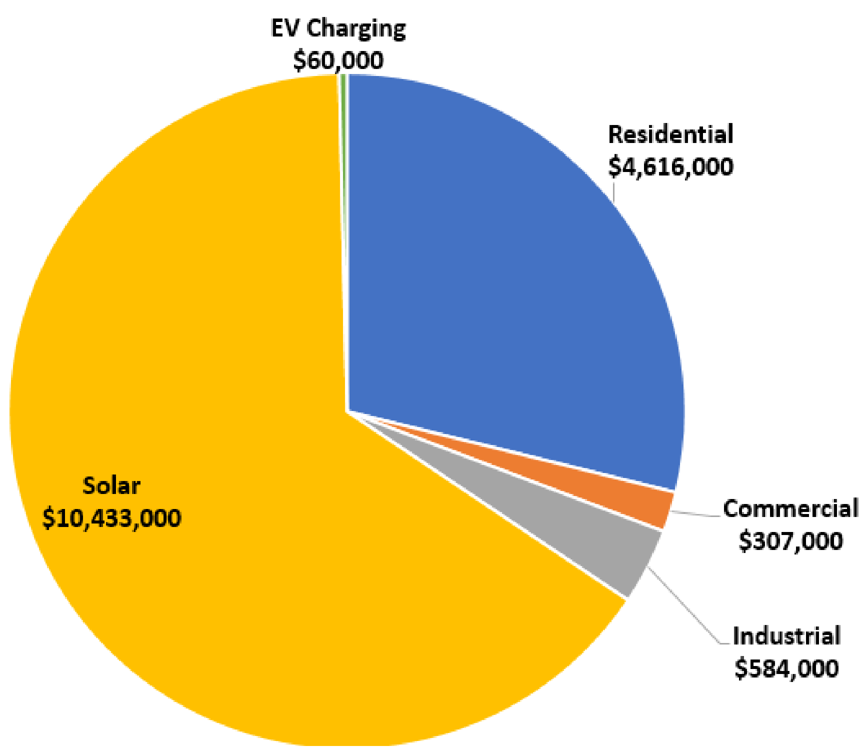
Source: Altura Associates

Table B-31: Case P Community Energy Usage Breakdown by Energy Source

	Total Annual Energy Savings (MMBTU)	Percent Reduction (%)	Annual Electric Energy Savings (MWh)	Percent Reduction (%)	Annual Nat. Gas Energy Savings (therms)	Percent Reduction (%)
Baseline Energy Usage	121,975	N/A	17,988	N/A	605,983	N/A
LED Lighting, Appliance and PPL Retrofit, and Residential DHW Retrofit	-13,480	-11.1%	-3,226	-17.9%	-22,426	-3.7%
Canopy Solar PV	-17,953	-14.7%	-5,262	-29.3%	0	0.0%
Final Community Energy Usage	90,542	-25.8%	9,500	-47.2%	583,557	-3.7%

Source: Altura Associates

Figure B-27: Case P Cost Breakdown



Source: Altura Associates

APPENDIX C: Solar Photovoltaic Scenarios

In addition to the maximum solar PV capacity scenario developed in the section on distributed energy resource potential in Chapter 8, three additional solar PV scenarios were developed using the heuristic solar PV design tool. These scenarios include the “grid constraint scenario” where solar PV is sized such that the solar PV system is capable of operating without storage, curtailment, or overloading the local utility grid, the “carport scenario”, where only carport solar PV is adopted, and the “utility scenario”, where only large solar PV systems are adopted to be placed on the utility side of the meter.

Under the grid constraint scenario, as shown in Figure C-1, each PV Zone in the community is given a limitation of the amount of PV can be deployed in that specific Zone. The determination is made based on the transformer rating such as power and voltage as well as the corresponding power flow. Those factors become the constraint for how much PV each zone could potentially have without causing the problem to the local power distribution system. Therefore, the PV installation potential has been dramatically reduced in the community. From maximum to grid constraint scenario, certain specific design criteria need to be considered to optimizing the system efficiency and maximizing energy output. After applying the methodology described in Chapter 1, the community’s total PV potential is reduced by almost 57 percent.

Figure C-1: Oak View Community Solar Photovoltaic System Overview under the Grid Constraint Scenario

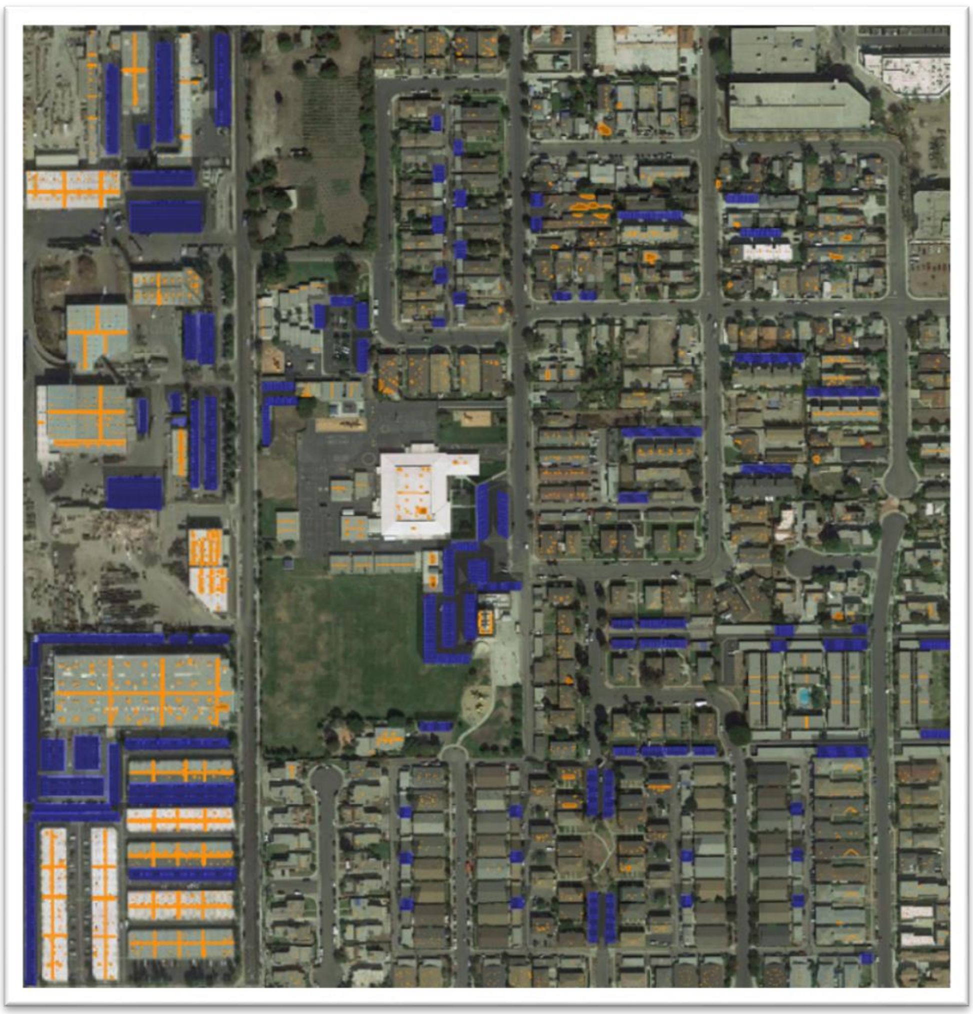
Source: University of California, Irvine

Table C-1: Constraint Scenario, Solar Photovoltaic Potential and Energy Production Broken Down into All Community Sectors

Oak View Community (Grid Constraint Scenario)	C&I Sector	School Sector	Residential Sector	Community Total
PV Capacity (MW)	3.62	0.66	1.74	6.02
Annual Production (GWh)	5.50	0.97	2.65	9.12
kWh/kW	1,521	1,463	1,525	1,515
System Performance (%)	79.5%	79.3%	78.4%	79.2%

Under this scenario, as shown in Figure C-2, remove all the rooftop PV arrays, and only count for carport PV which is designed based on the empty parking lot in the community. This scenario is supposed to estimate how much public carport PV structure cloud potentially exist without considering any carport PV design regulations and requirements (such as carport PV structure needs to be 20 feet away from permanent buildings). Those will be considered and included in the utility scenario. In the carport PV scenario, most carport PV array will be concentrated in the C&I and the School sector. There are several available carport PV potential locations in the Residential sector which could provide shade for public vehicles. The carport PV array in the residential sectors is usually small systems and likely to be scatted around, which could be a challenge for power local distribution compared with those large, concentrated, and continuous arrays in commercial sectors.

Figure C-2: Oak View Community Solar Photovoltaic System Overview under the Carport Photovoltaic Scenario



Source: University of California, Irvine

Table C-2: Carport Photovoltaic Scenario, Solar Photovoltaic Potential and Energy Production Broken Down into All Community Sectors

Oak View Community (Carport PV Scenario)	C&I Sector	School Sector	Residential Sector	Community Total
PV Capacity (MW)	2.64	0.48	0.99	4.11
Annual Production (GWh)	3.98	0.72	1.55	6.25
kWh/kW	1,509	1,504	1,567	1,521
System Performance (%)	81.8%	82.2%	82.2%	81.9%

In utility scenario, as shown in Figure C-3, most of the solar PV will be placed in C&I sector, with rest of the sectors with only carport PV system. Comparing with the carport PV scenario, all the carport PV in the community are designed based on regulations and rules. The PV capacity in each zone and sector are sized under the constraint from the grid. Comparing with the carport PV scenario, most of the small carport PV structure between car garages in South Residential and North Residential Sector cannot be built based on the design requirement that the canopy PV structure needs to be 20 feet from permanent buildings, which caused a dramatical reduction in solar PV capacity in the residential sector.

Figure C-3: Oak View Community Solar Photovoltaic System Overview under the Utility Scenario

Source: University of California, Irvine

Table C-3: Utility Scenario, Solar Photovoltaic Potential and Energy Production Broken Down into All Community Sectors

Oak View Community (Utility Scenario)	C&I Sector	School Sector	Residential Sector	Community Total
PV Capacity (MW)	4.27	0.40	0.33	5.00
Annual Production (GWh)	6.54	0.60	0.51	7.65
kWh/kW	1,533	1,512	1,552	1,530
System Performance (%)	81.4%	82.5%	82.6%	81.6%